research review

OAR: The Research Agency of The United States Air Force

VOLUME III NUMBER 11 JANUARY 1965

PROPERTY OF THE LIBRARY

16 MAR 1965

USAF ACADEMY

Electric Currents Around The Sun

SPACE PHYSICS LABORATORY, AFCRL

Space probes have detected electric currents of some 200,000 amps in the earth's ionosphere. Do similar currents flow around other bodies in space such as the sun? Marvin L. White of AFCRL's Space Physics Laboratory has predicted that the sun is encircled by "rings" of electric current totaling nearly 200 billion amps, most of which are in the sun's lower corona.

White is the first to predict such currents for the sun. Previously, no one had postulated the existence of such currents for two reasons. In the first place, it has been generally assumed that space has infinite conductivity. This implies that any electric currents in space would be infinite, which is impossible. In addition, the lines of force of the sun's magnetic field did not appear to have the orientation required to produce electric currents by acting on the streams of ionized hydrogen flowing from the sun. Photographs of the sun, taken during eclipses, in which the sun's coronal glow outlines its magnetic field, show the magnetic lines of force going straight out from the sun in a radial direction (in contrast to the earth's magnetic field in which the lines of force coming out of one pole bend around and connect with the other pole). Thus the sun's lines of force are parallel to the direction in which hydrogen ions are streaming out from the sun, so that no current would develop. (Electromagnetic theory states that in order for such a current to develop there must be a component of the magnetic field which is perpendicular to the direction of flow of the charged particles.)

However, White did not see why we should assume that space has infinite conductivity, particularly near the sun where there should be enough particles to give space some resistance to the flow of an electric current. He also noted that there were no radial lines of force coming from the sun near its equator. This meant that there could be lines of force, though too weak to detect, which were perpendicular to the flow of ionized hydrogen from the sun's equator, and therefore capable of generating a current by acting on this flow.

He applied both classical electromagnetic theory and modern magnetohydrodynamics to the problem. The electric currents are generated by the action of the sun's magnetic field on the streams of ionized hydrogen emitted by the sun. Once these currents develop, they distort the sun's primary magnetic field in such a way as to increase its current-producing "dynamo effect." Thus, ring currents would increase indefinitely if the dynamo effect were the only factor involved. However, charged particles flowing in large quantities through a magnetic field will strengthen or weaken the field depending on the direction of the flow and the shape of the field. In the sun's case, the outward flow of ionized hydrogen weakens the sun's magnetic field. This MHD effect "competes" with the dynamo effect to keep the system in equilibrium.

Although the total current in the sun's ring current system is very high, the current density (number of amperes flowing across a unit area) is low because the current is spread over a large area. According to White, it should be about three trillionths of an ampere per square cm. This is the same order of magnitude as the current density in the earth's atmosphere. White based his numerical calculations on particle flux data from Mariner II.

How will White's prediction affect solar theory and observation? Certainly it is difficult to verify the existence of the sun's ring currents by direct observation. Probably the only way to detect them is to measure their effect on the sun's magnetic field.

White's theory also predicts that the magnetic moment (essentially the "volume" of a magnetic field, given in units of gauss, multiplied by cubic cm) of the sun's magnetic field will be several orders of magnitude greater than is generally assumed.

Since 90 per cent of the mass in the universe consists of ionized gases, and since space is permeated with large, weak magnetic fields, dynamo current systems, such as the one predicted by White, may have played an important role in the formation of the solar system and the galaxy. ★

research review
OFFICE OF AEROSPACE RESEARCH

OAR RESEARCH REVIEW is published monthly by the Office of Scientific and Technical Information (RRYC), Hq Office of Aerospace Research, USAF, 4th and Independence Avenue, S.W., Washington, D.C. 20333. The objective of this publication is to make a positive contribution to the exchange of information concerning Air Force conducted and sponsored research activities. Individuals or organizations interested in or associated with research may obtain copies without charge by written request to the above address.

JACOB SEIDEN
Editor

OAR 63-1

ELECTRIC CURRENTS AROUND THE SUN
Space Physics Laboratory, AFCRL.....1

PREDICTING PRESSURE RATIOS FOR SUPERSONIC EJECTORS
1st Lt Alfred C. Pinchak.....3

NEW SHIPBOARD BALLOON-LAUNCH TECHNIQUE DEMONSTRATED
Francis X. Doherty.....6

OPTIMIZATION OF AERIAL DEFENSE PATROLS FOR DETECTION OF AERIAL TARGETS
Mary D. Lum.....8

CALCULATION OF ATOMIC STRUCTURES BY MEANS OF HARTFREE-FOCK WAVE FUNCTIONS
Thomas K. Krueger..... 10

CESIUM-PLASMA RESEARCH
1st Lt John A. Decker, Jr. 4

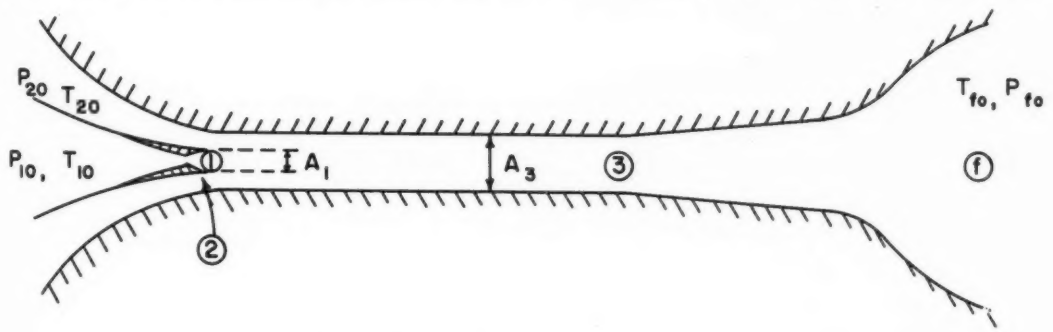
predicting pressure ratios for supersonic ejectors

1st LT ALFRED C. PINCHAK
Thermomechanics Research Laboratory, ARL

The problem of designing gas-gas, supersonic ejectors has received attention for some time. Currently, there is considerable interest in supersonic ejectors with regard to their utilization in space power systems and other energy-conversion methods which incorporate no rotating machinery. The purpose of a supersonic ejector is to utilize a high-velocity stream to entrain a secondary stream and thus move the secondary stream against an adverse pressure gradient. Essentially, such ejectors are simply gas-gas jet pumps. A cross-sectional view of a typical supersonic ejector is shown in Fig. 1. The primary or supersonic stream (1) is injected coaxially into the secondary (2) subsonic stream. With a sufficiently long mixing section, the two streams are thoroughly homogenized before entry into the diffuser; the resulting stream at station (3) is subsonic. Additional pressure recovery is obtained as the flow decelerates through the diffuser to stagnation conditions (f).

In correlating experimental ejector data, the use of one-dimensional conservation equations has proven adequate. However, in predicting the performance of a given ejector, it has been necessary to either simultaneously solve the algebraic conservation equations, numerically, or assume a value for some internal-flow parameter which is <u>not</u> known a priori, but only after an experimental test. Such typical internal-flow parameters might be the secondary-stream Mach number, or static pressure at the entrance to the mixing section, or the final Mach number at the end of the mixing section.

Most of the experimental work to date, with supersonic ejectors, has been directed toward producing relatively large values of the overall pumping or pressure ratio (P_{f_o}/P_{2_o}) with relatively small secondary flows ($\dot{m}_2/\dot{m}_1 \ll 1$). The work described here is concerned with ejectors operating at approximately equal-mass flows in the primary and secondary streams. A simple relation is derived which predicts the pressure ratio of this type of



$$T_{10} = T_{20} = T_{30}$$
$$A_1 + A_2 = A_3$$
$$M_1 > 1,\ M_2 < 1,\ M_3 < 1$$

FIG. 1 SKETCH AND NOTATION FOR SUPERSONIC EJECTOR

ejector without a priori knowledge of unknown internal-flow parameters. Some typical experimental data are given and compared with the above method of calculating P_{f_o}/P_{2_o}.

Simplified Expression for Ejector Pressure Ratio

Consider an ejector with a constant-area mixing section in which the primary stream enters supersonically, and the secondary stream subsonically. Both entering streams are perfect gases and are considered to be essentially one-dimensional. With the mixing tube sufficiently long, the mixed flow at the exit will be subsonic and approximately one-dimensional. The wall-shearing stress of the mixing tube is neglected. By assuming isentropic flow of both streams up to the mixing-tube entrance, and isentropic diffusion of the mixed stream to stagnation conditions, conservation of momentum requires that

$$\frac{P_{f_o}}{P_{2_o}} = \frac{P_{1_o}}{P_{2_o}} \frac{A_1}{A_3} \frac{\Gamma(M_1)}{\Gamma(M_3)} + \frac{A_2}{A_3} \frac{\Gamma(M_2)}{\Gamma(M_3)} \quad (1)$$

where

$$\Gamma(M_i) \equiv \frac{1 + k_i M_i^2}{\left\{1 + \frac{k_i - 1}{2} M_i^2\right\}} \frac{k}{k-1} \quad (2)$$

Fig. 2 is a plot of $\Gamma(M_i)$ vs M_i with the ratio of specific heats (k) as a parameter. Since $M_3 \neq 0$, even with zero secondary flow ($M_2 = 0$), a suitable average value of $\Gamma(M_3) = 1.25$ (for $k = 1.4$) is inserted in the first term on the right hand side of Eqn. 1. Because of the small variation of $\Gamma(M_i)$ with M_i for $0 \leq M_i \leq 1$, the second term in Eqn. 1 will be approximated by A_2/A_3.

The fact that M_3 increases, in general, with increasing M_2 aids in the accuracy of

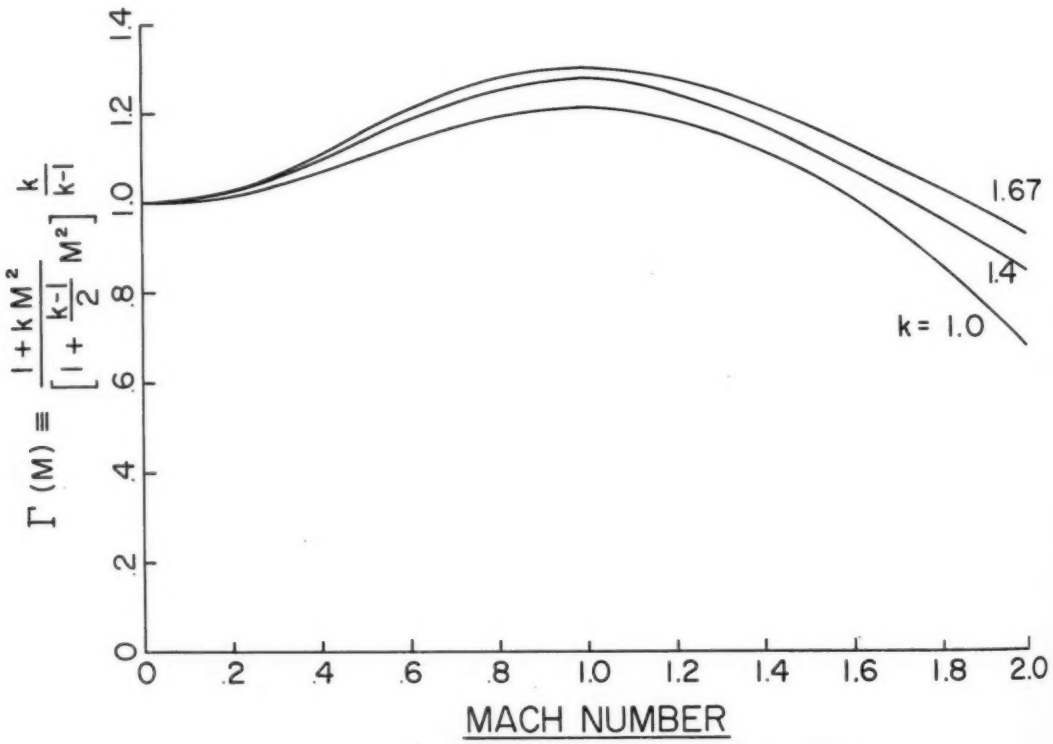


FIG. 2 Γ FUNCTION VS MACH NUMBER

the last approximation. Thus, the final approximate expression has the form

$$\frac{P_{f_o}}{P_{2_o}} = \frac{P_{1_o}}{P_{2_o}} \frac{A_1}{A_3} \frac{\Gamma(M_1)}{1.25} + \frac{A_2}{A_3} \qquad (3)$$

Note that Eqn. 3 requires only the area ratios, the upstream stagnation pressure ratio, and the value of the primary supersonic Mach number. All these parameters are specified before any experimental measurements are performed.

Comparison with Experimental Data

A plot of the value of $P_{f_o/P_{2_o}}$ computed from Eqn. 3 vs experimental values of $P_{f_o/P_{2_o}}$ is shown in Fig. 3. In view of the simplifications and assumptions inherent in Eqn. 3, the accuracy is rather remarkable. The experimental data presented here were taken with similar primary and secondary fluids (air) and stagnation temperatures (room temperature). However, Eqn. 3 should also be reasonably exact for both differing fluids and initial stagnation temperatures. This is due to the insensitivity of $\Gamma(M_i)$ with both k_i and M_i in the subsonic range. Thus, even with widely different k_i values for the two streams and different stagnation temperatures, the average magnitude of $\Gamma(M_3)$ will not differ considerably from 1.25, and $\Gamma(M_2)/\Gamma(M_3)$ will still be close to unity. ★

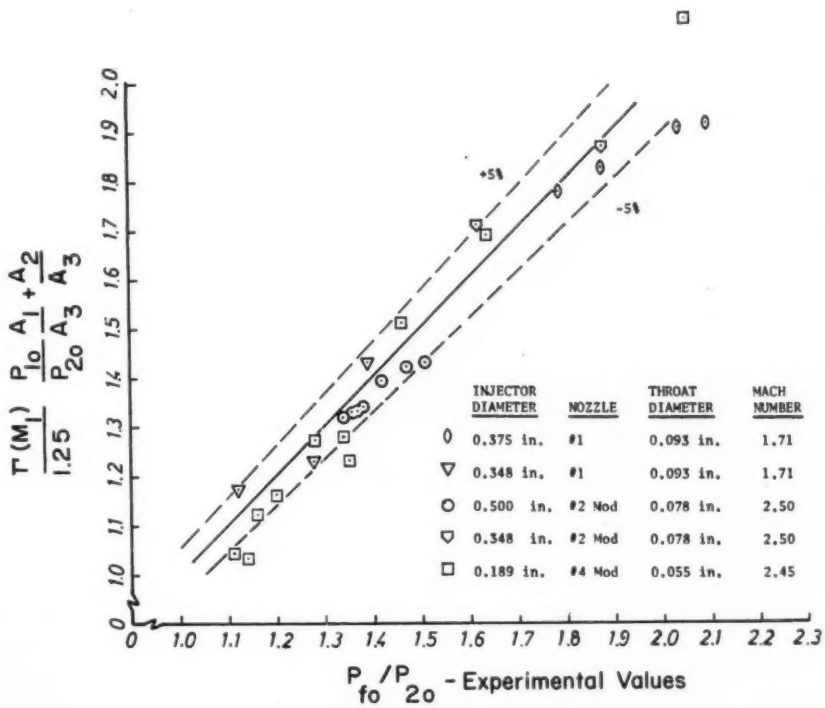
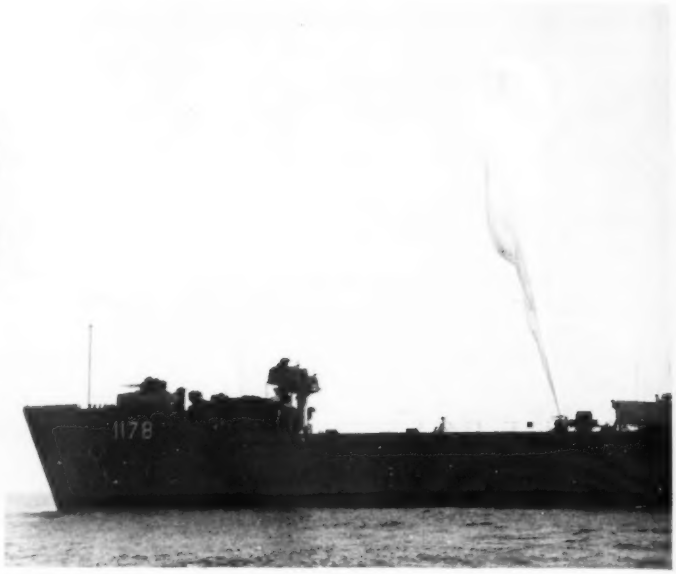

$\frac{\Gamma(M_1)}{1.25} \frac{P_{1o}}{P_{2o}} \frac{A_1}{A_3} + \frac{A_2}{A_3}$
0 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
0 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3
P_{fo}/P_{2o} - Experimental Values
+5%
-5%
INJECTOR DIAMETER | NOZZLE | THROAT DIAMETER | MACH NUMBER
0 0.375 in. #1 0.093 in. 1.71
▽ 0.348 in. #1 0.093 in. 1.71
○ 0.500 in. #2 Mod 0.078 in. 2.50
▽ 0.348 in. #2 Mod 0.078 in. 2.50
□ 0.189 in. #4 Mod 0.055 in. 2.45

FIG. 3 COMPARISON OF THEORETICAL AND EXPERIMENTAL EJECTOR PERFORMANCE

new shipboard balloon-launch technique demonstrated

FRANCIS X. DOHERTY
Aerospace Instrumentation Laboratory, AFCRL



Wind is the basic problem in launching large research balloons on land. Difficulties increase in direct proportion to surface wind velocities. The giant lightweight plastic balloons present a huge cross section to winds, the slightest of which exert a heavy force against the balloon.

During inflation, and especially at the time of launch, the balloon should stand vertical. At the time of launch, a special launch vehicle is used to carry the pay load. It literally moves at a speed matching that of the surface wind in order to maintain the vertical position of the balloon. An obvious limitation to this procedure is usable terrain. Aircraft runways are used in order to allow sufficient running space, and are excellent launch pads, provided the wind and runway directions are the same.

Wind-created difficulties associated with balloon launches can be overcome quite simply by launching the balloon from aboard ship. The ship can run with the wind and create a calm condition on the deck where the balloon is laid out and launched. Large balloons have in fact been launched very successfully from the decks of aircraft carriers. Carriers provide large amounts of flat deck space for laying out the balloon for inflation and launch. But aircraft carriers have the disadvantage of high operating cost.

This has led AFCRL to develop a unique launch technique suitable for operational use on small ships. The new technique was successfully demonstrated by AFCRL in August 1964 from the deck of a Navy LST off the coast of Virginia. The need for expansive deck space is eliminated by inflating and deploying the balloon directly from its shipping crate. A vital part of the technique is a special launcher device which was designed and fabricated at AFCRL. This electro-hydraulic device consists mainly of a system of rollers through which the balloon is controlled during inflation and deployment. The launcher weighs 2,000 pounds and measures 7 feet on each side.

Using polyethylene balloons having a fully deployed diameter of 107 feet, and carrying an 1,800-pound pay load, 4 launches were successfully conducted without incident from the USS Wood County LST-1178 in true surface wind conditions up to 17 knots--winds usually prohibitively high for land launches. The ship-deck space required for these operations measured approximately 30 by 60 feet. It is believed that this new balloon-launch technique will have definite application in remote-area operations. The launching system is presently being modified and refined to accommodate pay loads up to 4,000 pounds. ★

Shipboard launch of balloons from a Navy LST is demonstrated in these photos taken last August. This technique offers two advantages: first, such shipboard launches can be made from all over the world; second, and perhaps more important, such launches circumvent wind problems, the single most difficult aspect of launching a balloon. The speed of the ship can match exactly the speed of the wind, thus permitting the balloon to remain vertical during inflation and launch. The top photo shows the shipboard balloon launcher designed and built by AFCRL engineers.

OPTIMIZATION of AERIAL DEFENSE PATROLS for DETECTION of AERIAL TARGETS

MARY D. LUM
Applied Mathematics Research Laboratory
ARL

The problem stems from a study on the feasibility of an air command post in a counterinsurgency (COIN) operation. A question concerning the effectiveness of a back-and-forth patrol, with circular radar coverage, in detecting aerial targets motivated an in-house operations research study. This led to a mathematical formulation of moving-target-by-moving-patrol detection where the patrol employs repetitious pattern movements. Some examples of typical patrol patterns are shown in Figure 1.

The most essential idea pervading the theory involves the division of the four-dimensional space-time target region into two nonoverlapping subregions characterized as follows: those target points which can be detected at least once, and those target points which can never be detected by the patrol. Furthermore, each target point in the detectable region, known as "detection region," has uniquely associated with it the number of times it can be detected and the corresponding durations of detection. In Figure 2, the shaded portions of the full-cycle target region will be detected, and the unshaded portions will not be detected. From this point of view, for a given detection probability, maximization of the "effective patrol length," defined as the distance policed by the patrol, becomes the proper focal point of interest rather than maximization of the actual distance the patrol moves, the

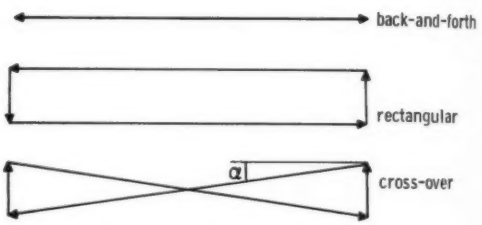


FIG 1. PATROL PATTERNS

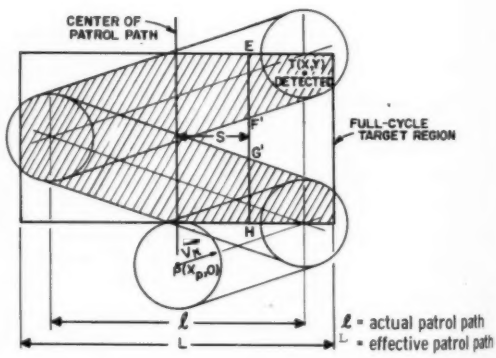


FIG. 2 DETECTION REGION SUPER IMPOSED ON FULL - CYCLE TARGET REGION FOR PATROL INITIALLY AT ARBITRARY POINT P WITH ψ_T = -90° (BACK-AND-FORTH PATTERN)

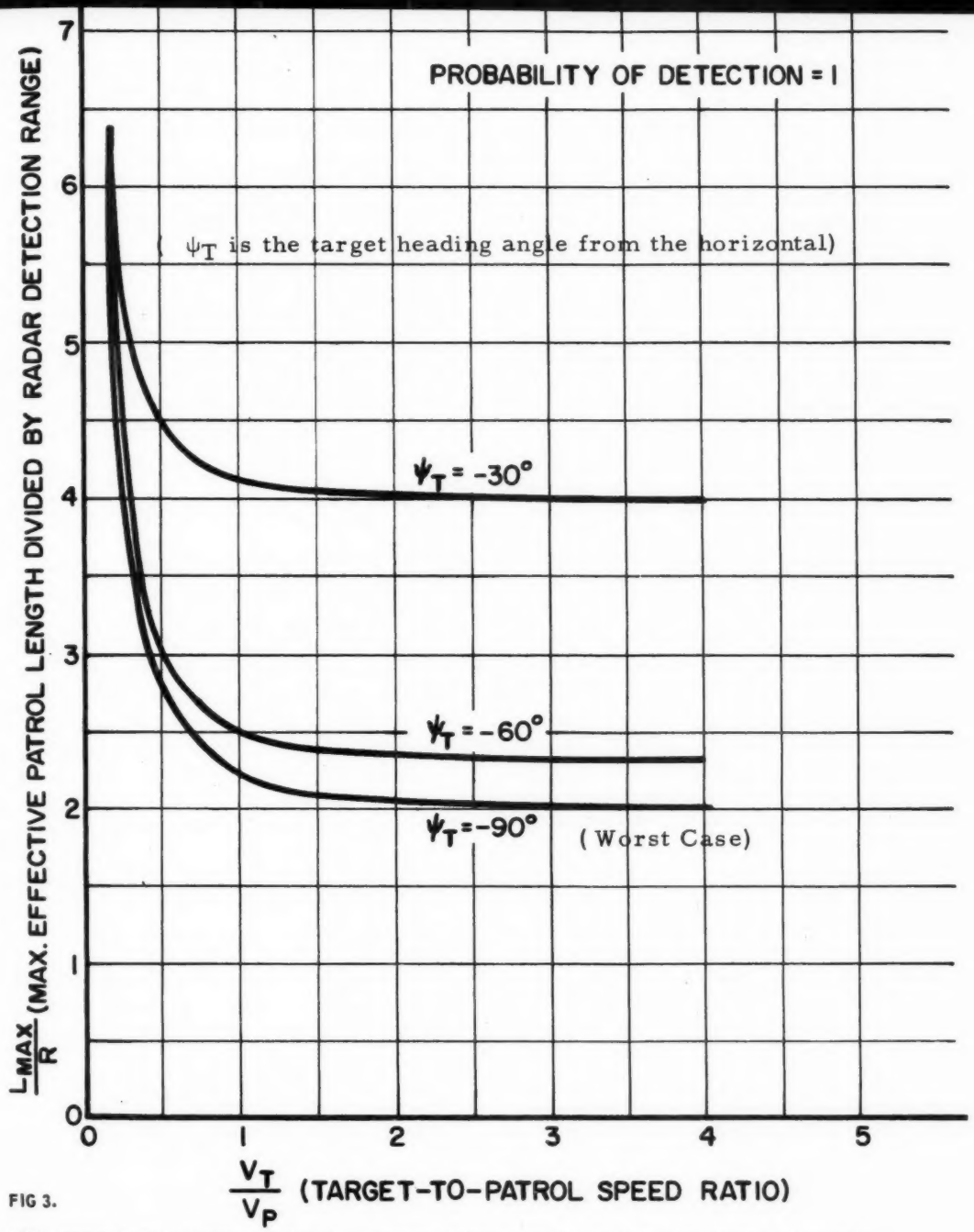


FIG 3.

MAX. EFFECTIVE PATROL LENGTH vs. SPEED RATIO FOR $\bar{p}=1$ (BACK-AND-FORTH PATTERN)

latter being of secondary concern in determining patrol effectiveness per se. Figure 3 shows the maximum effective patrol length vs target-to-patrol speed ratio for target headings $\Psi_t = -90^o$, -60^o, -30^o, where the average probability of detection is equal to unity. Other variables taken into account include the effects of radar range, patrol speed, target speed, target heading, relative velocity heading of patrol to target, and distance of target from center of patrol path. When quantifying the average probability of detection, defined as the proportion of target points detectable, one finds it necessary to specify

two further concepts: the "full-cycle" target region, and the duality relationship in relative motion.

The approach is novel and represents an attempt to probe deeply into a realistic, meaningful measure of detection capability--the average detection probability--while taking into account variations in essential parameters. To the writer's knowledge, only one other attempt of this nature is described in the research literature. However, that work was based primarily on the detection of ships with the target heading assumed known in advance. Such a restrictive assumption necessarily limits the possible application of that technique. In contrast, this proposed method does not need to depend on such an assumption, and is therefore more generally useful. For example, lower bounds on patrol detection probabilities can be calculated which furnish conservative estimates when no information is available on what the target headings will be. Better estimates of the detection probabilities can be calculated requiring only fragmentary bits of information about the target headings.

A substantial portion of this study will be reported in a forthcoming ARL Technical Report. The latter gives, for the back-and-forth pattern, numerical results of the detection probability in the "worst case" with respect to patrol detection probability: namely, the one in which the target heading is perpendicular to the patrol path. To illustrate the use of the derived equations and graphs for the back-and-forth pattern, two hypothetical examples are given: a patrol system in continental air defense, and a limited-war air-defense COIN (counterinsurgency)-type of operation.

Work is currently in progress to compute, for the back-and-forth pattern, the detection probabilities corresponding to the general target-heading angle. Further work is anticipated to compare the effectiveness of typical patrol patterns, such as "cross-over" or "rectangular," using the theory already developed. A conjecture to be verified is that the back-and-forth pattern, besides being the simplest, is generally the optimum pattern with respect to maximizing detection probability.

CALCULATION OF ATOMIC STRUCTURES BY MEANS OF HARTREE-FOCK WAVE FUNCTIONS

THOMAS K. KRUEGER
General Physics Research Laboratory, ARL

Accurate atomic wave functions are necessary for solving problems in such diverse fields as atomic physics, solid-state physics, and weapons effects. Here, at the General Physics Research Laboratory, we are primarily interested in the wave functions of free atoms and ions which are of astrophysical interest. Of particular interest are atoms or ions having 2, 3, or 4 electrons in an outer 2p or 3p shell, which are found in gaseous nebulae and the solar corona. The wave functions are used in determining radiative transition probabilities and excitation cross sections due to electron impact. This information is ultimately used in learning certain physical conditions of these astrophysical systems, such as the electron density and temperature of the system in question.

Hartree-Fock-type wave functions are currently accepted as the best available for calculating transition probabilities and excitation cross sections. These wave functions form a one-electron representation for atomic configurations; in this one-electron representation, each electron is assumed to move independently of the motion of the other electrons. Its behavior is described by a product of a function of its space coordinates and a function of its spin; such a product function is referred to as a "spin-orbital." The simplest representation of the wave function for all the electrons, then, would be a product of all the spin-orbitals

representing each of the electrons; but this does not satisfy the antisymmetry principle of Dirac which refers to the antisymmetry of the wave function under the interchange of two of the electrons. A wave function satisfying this requirement is a determinant of the spin-orbitals of the individual electrons. If the total wave function is Ψ, and the spin-orbital of electron i in state α is $\varphi_\alpha(i)$, then

$$\Psi = A \begin{vmatrix} \varphi_1(1) & \varphi_1(2) & \cdots & \varphi_1(n) \\ \varphi_2(1) & \varphi_2(2) & \cdots & \varphi_2(n) \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \varphi_n(1) & \varphi_n(2) & & \varphi_n(n) \end{vmatrix} \qquad (1)$$

is a wave function for an atom with n electrons; A is a normalization constant. Complicated configurations of electrons may require a sum of such determinants.

Regardless of the form of the total wave function Ψ, there is the relationship between it and the energy, E, of the system given by

$$E \leq \frac{\int \Psi^* H \Psi \varphi \tau}{\int \Psi^* \Psi \varphi \tau} \qquad (2)$$

which is the familiar variational principle. In Eq. (2) the asterisk means complex conjugation, the integral sign implies integration over all space coordinates and summation over all spin coordinates and H, the Hamiltonian, is given in atomic units by

$$H = -1/2 \sum_{i=1}^{n} \nabla_i^2 - \sum_{i=1}^{n} \frac{Z}{r_i} + \sum_{i<j}^{n} \frac{1}{r_{ij}} \qquad (3)$$

In Eq. (3) ∇_i^2 has the usual meaning (the Laplacian), Z is the nuclear charge, r_i is the distance of electron i from the nucleus and r_{ij} is the separation of electrons i and j. The equality sign holds in Eq. (2) if Ψ is the exact wave function of the system, and if Ψ is correct to order m, the energy computed by the right side of Eq. (2) is correct to order 2m. Therefore, Ψ may be varied and the best choice of Ψ is the one which makes the right side of Eq. (2) a minimum. What is done to accomplish this variation is to vary

$$\int \Psi^* H \Psi \varphi \tau$$

subject to the constraints that the $\varphi_\alpha(i)$'s be normalized and that any two different $\varphi_\alpha(i)$'s be orthogonal if they have the same spin projection quantum number; this is done by the method of Lagrangian multipliers.

If the variation is carried out and the separation-of-variables technique is used with spherical coordinates, it is found that the angular part of the spin-orbital is the familiar spherical harmonic, and that the radial part is 1/r times the solution of the following equation:

$$\frac{\varphi^2 P_\alpha}{\varphi r^2} + \left\{ \frac{2}{r} Y_\alpha(r) - \epsilon_{\alpha\alpha} - \frac{\ell_\alpha(\ell_\alpha+1)}{r^2} \right\} P_\alpha(r) = X_\alpha(r) \qquad (4)$$

The function $Y_\alpha(r)$ depends on the nuclear charge and the radial parts of all the spin-orbitals. The constant, $\epsilon_{\alpha\alpha}$, called the one-electron energy parameter, is related to one of the Lagrangian multipliers. The constant, ℓ_α, is called the angular momentum quantum number and may take the values 0, 1, 2, ... etc. The function $X_\alpha(r)$ depends on the radial parts of all the spin-orbitals and also contains other constants related to Lagrangian multipliers. To get a numerical solution of Eq. (4), it is necessary to use a self-consistent iterative technique because of the functional form of $Y_\alpha(r)$ and $X_\alpha(r)$. The usual procedure is to start with a good set of trial values for all the P_α and then calculate new values using each new P_α in $Y_\alpha(r)$ and $X_\alpha(r)$ for the next iteration. This process is repeated until there is no change, to the accuracy desired, in each P_α between succeeding iterations. Then one ultimately has a table of values for each P_α from which physical quantities of interest can be calculated.

In the General Physics Research Laboratory, we have computed these functions for about 75 atoms and ions. More will be computed in the future, and the results will be published periodically. ★

ARL SCIENTISTS

Dr. Hans J. P. von Ohain

Major Melvin R. Keller

TS REAP TOP HONORS

Dr. Harry A. Lipsitt

These three ARL scientists, Dr. Hans J. P. von Ohain, Major Melvin R. Keller, and Dr. Harry A. Lipsitt, recently captured the first- and third-place awards at the 11th Annual Air Force Science and Engineering Symposium held at Brooks AFB, Texas. Dr. von Ohain, Chief Scientist at ARL, and Major Keller, who is with the Thermomechanics Research Laboratory, won the first-place award for their paper, "Research Relevant to the Gas Core Reactor." Dr. Lipsitt, supervisor of metallurgy research at the Metallurgy and Ceramics Research Laboratory, received the third-place award for his paper, "Crack Propagation in Cumulative Damage Fatigue Tests."

The Air Force Science and Engineering Symposium is held annually to demonstrate the capability of the Air Force and the competence of its scientists and engineers to conduct and manage high-quality in-house research programs. Particular emphasis is laid on the spectrum of science and engineering activity as conducted by the Office of Aerospace Research and the Air Force Systems Command.

The awards to these scientists were made on the basis of interest, quality and competence, and were presented by the OAR commander, Major General Don R. Ostrander.

CESIUM-PLASMA RESEARCH*

1st LT JOHN A. DECKER, JR.
Plasma Physics Research Laboratory, ARL

The physics of cesium and cesium plasma has been studied since the 1920's. Recently, there has been a great surge of interest in cesium for experimental purposes over the whole spectrum of plasma physics. This stems from cesium's low ionization potential (3.89 ev) which allows the generation of plasmas with nearly total ionization at moderately high electron densities. This feature can be utilized in the synthesis of plasma configurations in controlled thermonuclear reactor research. Cesium-plasma research has potential application (1) in the direct conversion of heat energy to electrical power, (2) in magnetogasdynamic power generation, and (3) in electrical-rocket propulsion.

Historically, the first plasma sources utilizing cesium were simple hot-cathode discharge tubes run at pressures from 1 to 1000 microns at currents up to several amperes. Plasma ion densities of up to 10^{13} per cm^3 at 1 ev with 10-to-50-per-cent ionization were achieved. Variations of this simple device have evolved to include a great variety of plasma-generating apparatus. A major class of present cesium-plasma generating devices is the "thermal" or "synthetic" plasma machine using "resonance" ionization of cesium. Depending upon the sophistication of the apparatus, it is possible to produce plasma columns over 1 meter in length with ion densities above 10^{13} per cm^3 at nearly total ionization. In the "atomic-beam" mode of operation, neutral cesium atoms are ionized by impinging on a hot tungsten surface, and are re-emitted as singly charged positive ions. The tungsten surface is run hot enough for its thermionic emission to exactly balance the ion emission resulting in the generation of a "neutral" plasma. The resulting plasma column is confined by an axial magnetic field while the neutral gas background pressure is reduced by continuous operation of vacuum pumps and by cooling of the chamber walls to condense neutral cesium atoms.

Traditional measurement techniques in cesium discharges and plasmas employ spectroscopic methods and Langmuir probes to obtain electron temperature and density. Considerable effort has been expended in applying microwave diagnostic techniques to measure electron temperature and ion density. Each of these methods has drawbacks. The quiescent thermally generated cesium plasma emits very little light; thus, spectroscopic measurements are very difficult. The operation of probes and interpretation of measurements in cesium plasma are made difficult since cesium corrodes many metals, enters into complicated surface reactions with metals and glass, and condenses on probes even when the probes are hotter than their immediate environment. Microwave methods suffer from having to "average" measurements over a cross section of the plasma column or over the volume of the "interaction" region. Cesium vapor adversely affects optical pyrometer measurements and increases the sensitivity of ionization pressure gauges.

Measurements made on cesium plasmas fall roughly into three categories: (1) basic definition of the physics of cesium itself; (2) plasma diffusion and recombination studies, including the study of plasma transport properties; and (3) oscillation and plasma instability work.

Basic gas and atomic properties have been under study since the 1930's. The basic data is now "part of the literature" and is given in various tables, handbooks, and texts. Recently, advanced electronic and data-processing techniques have allowed more

accurate experimental measurements of ion/atom and charge-exchange cross sections which, in turn, have yielded more refined values for ion and electron mobilities in cesium plasma, calculation of wave functions of the various states of the cesium atom, experimental and theoretical determination of the thermal conductivity and viscosity of cesium vapor, etc.

Most diffusion measurements in the cesium plasma are directed to diffusion of a fully ionized plasma across a magnetic field primarily to verify "enhanced" or "convective" diffusion theory that was postulated to explain the anomalously high rate of particle loss in certain plasma-containment experiments in thermonuclear research. Measurements made on quiescent plasmas with zero net drift current have shown no "enhanced" effects to be present; calculated diffusion coefficients have agreed with classical ambipolar diffusion theory. Recent diffusion measurements in a current-carrying plasma indicated ambipolar diffusion up to a critical current density, and greatly enhanced diffusion accompanied by violent oscillations beyond this critical current density. Another experiment in a low-pressure cesium arc with an axial electric field indicated three separate diffusion regimes which were dependent on the magnitude of the magnetic field applied.

In contrast to the confused picture in diffusion research, recent recombination studies have clarified the results of previous research. Whereas early measurements of the volume-recombination coefficient in cesium plasma varied from 10^{-10} to 10^{-7} cm^3/sec depending upon the diagnostic technique, values of the order of 10^{-10} cm^3/sec have been achieved using probe, spectroscopic, and microwave techniques in various cesium plasmas.

Values of resistivity derived from the usual cesium-plasma configurations (discharge tubes, hot-cathode cesium arc, surface-ionization tube, Q-machine) have compared within ± 50 per cent of values computed by Spitzer's theory which uses values of electron temperature and ion density measured by spectroscopic, probe, or microwave methods.

Waves and oscillations in plasmas have been studied as long as have plasmas themselves. Current research on waves and instabilities in cesium plasma stems primarily from four stimuli: (1) the existence of oscillations in cesium-diode direct-conversion devices and most laboratory cesium-plasma apparatus; (2) the desire to use plasma-wave interactions as an amplification technique at very-high frequencies; (3) the general interest in plasma instabilities that is a by-product of controlled thermonuclear reactor research; and (4) the high fractional ionization and high ionic weight of cesium plasma that make it ideal to study low-frequency ion-driven waves and instabilities. ★

** This article is a condensed version of the report, A Survey of Cesium-Plasma Research, ARL 64-220.*

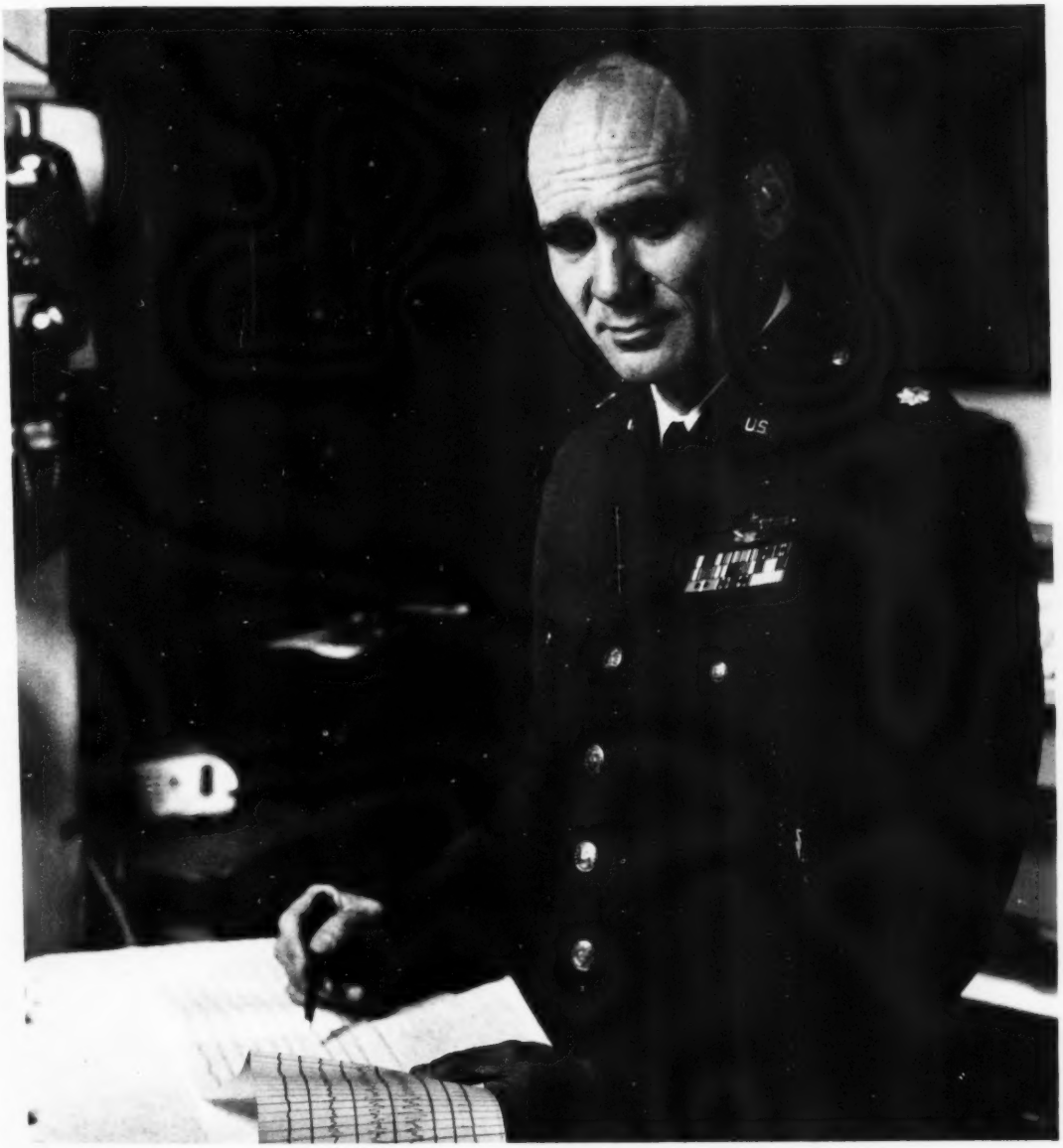
SCIENTIFIC NOTE

Chinese Nuclear Test: Three minutes before the explosion of the Red-Chinese nuclear-test package at 0700 GMT on 14 October 1964, an earthquake occurred in Mongolia. From the AFCRL standpoint, this was an unfortunate coincidence. The earthquake precluded the possibility of detecting the nuclear explosion by AFCRL's network of 4 automatic seismic stations. Data from these 4 stations (3 in Maine and 1 in New Hampshire) are monitored at a main station in Weston, Mass. Although the low yield of the explosion and its occurrence in the atmosphere may have made seismic detection impossible in any event, the earthquake, which was recorded in New England 15 minutes after its occurrence, saturated what would have been the weaker seismic signal. The AFCRL stations, however, did record the underground nuclear test which took place in Mississippi on 22 October 1964. This explosion was only about 1/4 the size of the Hiroshima one. (Terrestrial Sciences Laboratory AFCRL.)

OAR PROFILES

Mary D. Lum, a research mathematical statistician with the Applied Mathematics Research Laboratory, ARL, is currently working on the analysis of variance and probability. This embraces two efforts: one effort is directed towards an understanding of fundamental questions in the analysis of variance, a subfield of the design and analysis of experiments; the other effort is the development of probabilistic models for applied mathematical problems. Miss Lum has an A.B. with honors in Mathematics and Physics (1945), and an M.A. in Statistics (1946), both from the University of California. She is listed in American Men of Science (Physical and Biological Sciences), 10th Edition, and in Who's Who Among American Women (3rd Edition, 1963-1964, now being published). She has a number of publications to her credit. In this issue of the Review, Miss Lum writes on "Optimization of Aerial Defense Patrols for Detection of Aerial Targets."

Mr. Marvin L. White, a research physicist with the Space Physics Laboratory, AFCRL, is currently studying solar physics and interplanetary climatic conditions. While at the Boulder Laboratories of the National Bureau of Standards (before coming to AFCRL in 1961), he worked in the field of atmospheric tides. His research in this area led to his discovery of a universal law governing the behavior of semidiurnal tidal winds from sea level to 100 Km. Mr. White has a B.A. in Physics from the University of Texas (1939), an M.A. in Physics from the University of Missouri, and an M.S. in Astronomy and Astrophysics from the University of Chicago. He has written a number of publications and is a member of several professional societies. His current research is described in this issue of the Review in the article, "Electric Currents Around the Sun."



Major Robert A. Gray, coauthor of the article, "Worldwide Survey of Small Earthquakes," which appeared in the December 1964 Review, is shown in the laboratory examining a seismic pen recording. He recently received the USAF Research and Development Award, given annually to outstanding military scientists, from the Air Force Chief of Staff, General Curtis E. LeMay. As Chief of the Wave Propagation Branch, Terrestrial Sciences Laboratory, AFCRL, Major Gray is responsible for the management of basic research in seismology. The major part of this research is for a Defense Department project, Vela Uniform, being conducted to find a reliable system for detecting and identifying underground nuclear explosions. Major Gray has a Bachelor's degree in Geology from the University of North Carolina (1950), and a Master's degree in Geophysics from St. Louis University (1960). He also holds the Air Medal for service during the Korean War.

First Lieutenant Alfred C. Pinchak is a research scientist with the Thermomechanics Research Laboratory, ARL. He is currently working in the general field of energy conversion, with special emphasis on fluid injectors and swirl-type flows. In addition, he is conducting fundamental studies related to gas phase condensation. Lt Pinchak has a BSEE in Electrical Engineering from the Case Institute of Technology (1957), an MSE in Jet Propulsion from Purdue University (1959) and a Ph.D. in Jet Propulsion from the California Institute of Technology (1963). He has taught at the California Institute of Technology, and has a number of publications to his credit. In this issue of the Review, Lt Pinchak writes on "Predicting Pressure Ratios for Supersonic Ejectors."

Mr. Thomas K. Krueger, a research physicist with the General Physics Research Laboratory, ARL, has been with ARL since 1955. During that time, he has worked on various tasks, beginning with the experimental neutron cross-section program on the Van de Graaff. Following that, his efforts were directed at improving the operating efficiency of crystal-type nuclear-radiation detectors, and accumulating information for monitoring the calculations of Air Force contractors on the reactor-shielding aspects of ANP (Aircraft Nuclear Propulsion). Currently, he is conducting an investigation on the optical model for neutron interactions with nuclei. Mr. Krueger has a B.S. (1953). from the College of St. Thomas, Minnesota, and an M.S. (1958) from the Air Force Institute of Technology. He writes in this issue of the Review on the "Calculation of Atomic Structures by Means of Hartree-Fock Wave Functions."

Dr. Louis Berkofsky is a research physicist with the Dynamics Branch, Meteorology Laboratory, AFCRL. From 1949 until the present, he has been engaged in work on numerical weather prediction. Currently, he is considering these problems: a theoretical solar-weather model; hurricane prediction; the effects of mountains on large-scale flows; generalized numerical forecasting models; and a numerical model of periodicity in equatorial stratospheric easterlies. Dr. Berkofsky has a B.A. in Mathematics from Brooklyn College (1946), an M.S. in Meteorology from New York University (1948), and a Ph.D. in Meteorology from M.I.T. (1958). He has a number of publications to his credit, and is a member of Sigma Xi and the American Meteorological Society. In the December 1964 issue of the Review, the article, "Hurricane Prediction," describes his current research efforts.

TO OUR READERS

Requests for further information should be directed to the individual or laboratory of origin (except for those from Latin America).

Addresses are as follows:

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
Attn: CRI
Laurence G. Hanscom Field, Bedford, Massachusetts 01731

AEROSPACE RESEARCH LABORATORIES
Attn: ARB
Wright-Patterson Air Force Base, Ohio 45433

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Attn: SRGL
Tempo D Building
4th and Independence Avenue, S.W., Washington, D.C. 20333

OFFICE OF RESEARCH ANALYSES
Attn: ORR
Holloman AF Base, New Mexico 88330

Requests for further information from institutions and individuals in Latin America should be addressed to:

LATIN AMERICAN OFFICE AEROSPACE RESEARCH
U. S. EMBASSY
Rio de Janeiro, Brazil

Detailed documentary reports may be obtained from:

CLEARINGHOUSE
U. S. Department of Commerce, Springfield, Virginia 22151

DEFENSE DOCUMENTATION CENTER FOR SCIENTIFIC AND TECHNICAL INFORMATION*
Cameron Station, Alexandria, Virginia 22314

* Qualified requestors

GPO 886-990

OAR (RRYC)
BLDG T-D
WASH, D. C. 20333
UNITED STATES AIR FORCE
OFFICIAL BUSINESS

POSTAGE AND FEES PAID
DEPARTMENT OF THE AIR FORCE

USAFA(DFSLB)
USAF Academy, Colo. 80840
REV 02/05

"RESEARCH - The Key to Aerospace Superiority"

research review

OFFICE OF AEROSPACE RESEARCH

OAR: The Research Agency
of The United States Air Force

VOLUME III NUMBER 12 FEBRUARY 1965

USAF ACADEMY

HIGH-PRESSURE CHEMISTRY

LT COL MILTON D. SPRINKEL
Directorate of Chemical Sciences, AFOSR

For centuries various pressure techniques have been used to force matter into desired physical shapes; but only recently have any significant efforts been made to investigate the effects of extremely high pressures on the chemical nature of materials.

Under an AFOSR grant at the University of California, Los Angeles, Dr. W. F. Libby is conducting an extensive program of research in the area of high-pressure chemistry. (1) (2) (3) (4) (5) (6) Dr. Libby is proceeding on the theory that, for any tetrahedral structure, the enforced increase in the number of nearest neighbors (above the four bonds possible for the available valence electrons) causes a crystal-wide resonance which is characteristic of the metallic state. Based on this theory it seems very likely that, if a suitable press could be built, it would even be possible to isolate metallic diamonds, i.e., diamonds in a much more dense state than the familiar synthetic diamonds, and which would exhibit metallic characteristics. (7) It has been estimated that the pressure of transition for carbon is approximately 600,000 atmospheres. While static pressures of this magnitude are beyond the capability of present equipment, it may well be that, within the next few years, it will be possible to produce metallic diamonds in good yields.

Meanwhile, it is certain that hundreds of new metals can be made now with presently available equipment. Dr. Libby and his coworkers have successfully transformed several semiconductor materials into metallic materials. These transformations have been achieved by subjecting the semiconductor materials to pressures of 25,000 to 50,000 atmospheres for a period of several hours, then chilling to liquid-nitrogen temperature (-197°C) while under pressure, and finally releasing the pressure to obtain the metal in a metastable form at atmospheric pressure.

By utilizing this process, with variations as necessary for each specific system, five (5) new metals, InSb, $InSbSn_1$, $InSbSn_2$, $InSbSn_4$, and InTe have been prepared. Some of their properties, such as the crystal geometry, crystal parameters, hardness, electrical conductivities, and superconductivities have been measured, and the results have been quite interesting. For example, indium telluride (InTe), ordinarily a semiconductor with tetragonal crystal structure,

is transformed into a metal with cubic structure at pressures above 32,000 atmospheres. This new metal is soft, has a beautiful blue color, does not revert to the semiconductor form until heated above 125°C, and is a superconductor at temperatures below 2.18°K.

While these new metals vary in some of their other properties, they have one very important characteristic in common--they are all superconductors. Figure 1 is a representation of the superconductivity temperatures of the indium-antimony-tin (InSbSn) system showing that there is a regular progression from the pure InSb metal to pure tin.

These new metals are distinctly unique in their electronic structure and behavior, and it is believed that further study of the hundreds of new metals which can be made by this new technique will contribute greatly to an understanding of mechanical strength and superconductivity. ★

REFERENCES

(1) Darnell, A. J. and W. F. Libby, "Indium Antimonide: The Metallic Form at Atmospheric Pressure," Science, 139, 1301, 1963.

(2) Bömmel, H.E., A.J. Darnell, W. F. Libby and B. R. Tittmann, "Indium Antimonide: Superconductivity of the Metallic Form," Science, 139, 1301, 1963.

(3) Darnell, A. J., A. J. Yencha and W. F. Libby, "Indium Telluride Metal," Science, 141, 713-, 1963.

(4) Bömmel, H. E., A. J. Darnell, W. F. Libby, B. R. Tittmann and A. J. Yencha, "Superconductivity of Metallic Indium Telluride," Science, 141, 714-, 1963.

(5) Darnell, A.J. and W.F. Libby, "Artificial Metals; InSb, the Sn Alloys with InSb and Metallic InTe," (to appear in the Physical Review).

(6) Tittmann, B.R., A. J. Darnell, H. E. Bömmel and W. F. Libby, "Superconductivity in the Artificial Metals; Metallic Indium Antimonide, the Indium Antimonide-Tin Alloys, and Metallic Indium Telluride," Phys. Rev., 135, A 1460-, 1964.

(7) Libby, W.F., "Theory of Metallic Diamond," Phys. Rev., 130, 548-, 1963.

research review
OFFICE OF AEROSPACE RESEARCH

OAR RESEARCH REVIEW is published monthly by the Office of Scientific and Technical Information (RRYC), Hq Office of Aerospace Research, USAF, 4th and Independence Avenue, S.W., Washington, D.C. 20333. The objective of this publication is to make a positive contribution to the exchange of information concerning Air Force conducted and sponsored research activities. Individuals or organizations interested in or associated with research may obtain copies without charge by written request to the above address.

HIGH-PRESSURE CHEMISTRY
Lt Col Milton D. Sprinkel.....1

PROJECT STORMY SPRING
Dr. Carl W. Kreitzberg.....4

DETERMINATION OF HOT-GAS-TEMPERATURE PROFILES FROM INFRARED EMISSION-AND-ABSORPTION SPECTRA
Dr. Bernard T. Wolfson.....5

SUNSPOT CYCLE AND IONOSPHERIC STORMS
Upper Atmosphere Physics Laboratory, AFCRL.....6

SPORADIC E NOT SO SPORADIC AFTER ALL
Upper Atmosphere Physics Laboratory, AFCRL.....7

THE ACM-ACMCP CONCEPT---A COMPUTER-ORIENTED CHEMICAL NOMENCLATURE .....
Dr. Leonard Spialter.....9

PHOTOGRAPHIC-RECONNAISSANCE BALLOON FLIGHT
Aerospace Instrumentation Laboratory, AFCRL.....11

"ACT FROM THOUGHT SHOULD QUICKLY FOLLOW---"
(Initiation of Muscular Contraction)
Captain Joel R. Lowenthal.....14

AN ULTRASTABLE MICROWAVE RADIOMETER
Microwave Physics Laboratory, AFCRL.....15

MEASURES FOR MEDITATION, OR, CAN WE QUANTITATIVELY DESCRIBE AND PREDICT HUMAN PERFORMANCE?
Rowena Swanson.....16

PERCEPTION IN THE WORLD OF SPACE
Dr. Robert E. Adamson.....18

LUNAR GEODESY--A PROBLEM IN STATISTICS
Mahlon Hunt.....19

ZERO-PHONON LINES AND PHONON COUPLING IN SPECTRA OF ZnS : Mn CRYSTALS
Dr. D. W. J. Langer.....20

IONOSPHERIC DUCTING CONFIRMED IN SATELLITE EXPERIMENT
Space Physics Laboratory, AFCRL.....22

JACOB SEIDEN
Editor

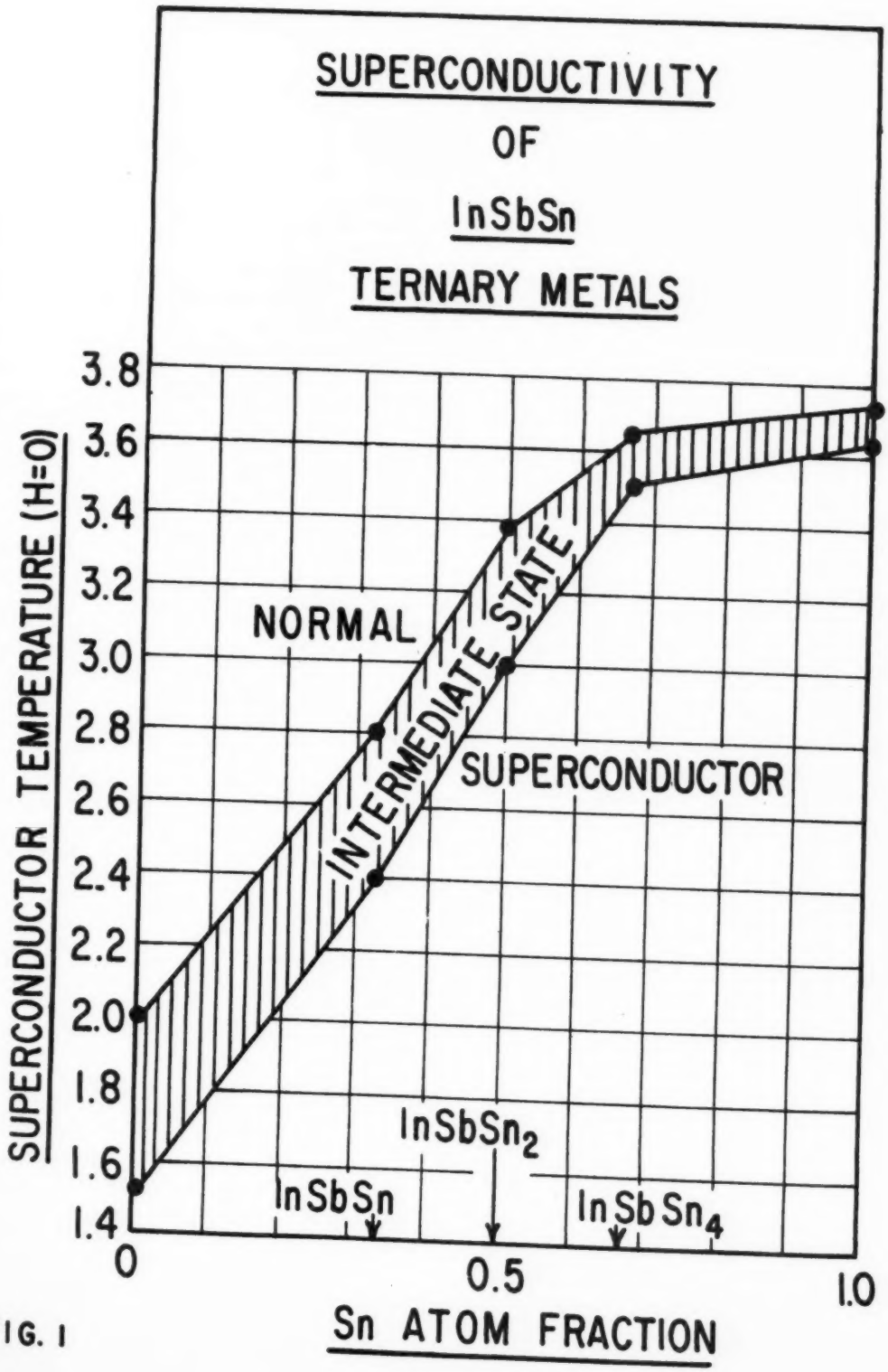

SUPERCONDUCTIVITY
OF
InSbSn
TERNARY METALS
SUPERCONDUCTOR TEMPERATURE (H=0)
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
NORMAL
INTERMEDIATE STATE
SUPERCONDUCTOR
InSbSn2
InSbSn
InSbSn4
0
0.5
1.0
Sn ATOM FRACTION

FIG. 1

PROJECT STORMY SPRING

DR. CARL W. KREITZBERG | Meteorology Laboratory, AFCRL

New England weather next spring will be examined in a manner never before attempted when AFCRL's "Project Stormy Spring" gets under way. AFCRL's U-2 and C-130 weather aircraft, weather radars, radiosondes and weather satellites will be used during concentrated periods of simultaneous observations of many aspects of particular weather systems.

The study will be concentrated largely in the southern New England states. Thus, technically, it will be concerned with mesoscale weather structures. (These structures might extend from 20 to 200 miles.) Mesoscale weather patterns have received far less attention from meteorologists than larger-scale patterns. But in weather prediction, mesoscale phenomena give the weather forecaster some of his greatest headaches. He may find, for example, that the 12-inch snowfall predicted 24 hours earlier did in fact occur--but 50 miles west of the city.

Although the AFCRL study will be concerned largely with gaining a better understanding of the dynamics of weather systems over a particular region, such an understanding is fundamental to the problem of more precise local forecasts.

Scientists from all the specialized branches of AFCRL's Meteorology Laboratory will participate in the intensive program of observation and analysis. "Stormy Spring" observations will be conducted between 15 March and 30 April 1965. During this period, 2 or 3 of the major storm systems which pass through the southern New England area will be observed by a host of techniques for continuous periods of 24 to 36 hours each.

Some of the goals of the project are: 1) to study the circulation and dynamics of cloud and precipitation bands, high- and low-level frontal zones and mesopressure systems; 2) to determine the distribution of moisture and precipitation, the mechanism of moisture balance and the physics of precipitation growth in various portions of the cyclones; 3) to evaluate the stratosphere-troposphere exchange processes by examining the ozone structure of the upper troposphere and lower stratosphere in relation to the associated circulations and thermal structures; 4) to develop and evaluate techniques of observation, data reduction and analysis for future studies of this type.

The US Weather Bureau and the Air Weather Service will assist AFCRL by taking some of the observations. Permanent and mobile radiosonde sites at about 60-mile spacing and operating at 90-minute or 3-hour intervals are a basic aspect of the data-gathering network. In addition, a special surface network established to gather wind,

temperature, pressure, humidity and precipitation data from 25 surface sites spaced 20 miles apart will be used.

A weather satellite will provide cloud photographs, as will also the C-130 and U-2 aircraft. In addition, the U-2 aircraft will measure ozone distribution, temperature, and wind and radiometric data; the C-130 will provide cloud-physics, temperature and wind data. Several weather radars, each with unique capabilities (one of these being a TPQ-11 recently installed at L. G. Hanscom Field) will also be used.

"Project Stormy Spring," as presently planned, will be one of the most massive and intensive programs for observing weather dynamics over a limited region that has yet been undertaken. ★

DETERMINATION OF HOT-GAS-TEMPERATURE PROFILES FROM INFRARED EMISSION-AND-ABSORPTION SPECTRA

DR. BERNARD T. WOLFSON
Directorate of Engineering Sciences, AFOSR

The temperature of the working fluid is a basic parameter in analyzing propulsion systems, whether chemical, nuclear, or electrical. Ideal models assume that the temperature is uniform throughout the volume of the working fluid but, in practice, large temperature gradients usually exist. These temperature gradients have effects on radiative heat transfer and over-all system performance. Measurement of the temperature distribution would be very useful to help evaluate these effects. Such measurements would be even more useful if the spectral emissivities of the inhomogeneous working fluid could be determined simultaneously with the temperature distribution.

Dr. R. Tourin and his co-workers at Warner-Swasey Company under AFOSR sponsorship (contract AF49[638]-1132), have studied the relationships between temperature distribution in a hot gas and the infrared emission-and-absorption spectra of the gas, with a view to determining gas-temperature profiles from line-of-sight spectral measurements. The spectral-emittance equation for an inhomogeneous hot gas was formulated in terms of the radiative contributions from a hypothetical set of isothermal zones along a line of sight through the gas. Each such contribution is expressed as a function of three observables: local temperature, local spectral emissivity, and reabsorption of radiation by the portion of the gas between the zone considered and the boundary of the gas. A set of these equations, for several wave lengths in the spectrum, can be solved in terms of the thermal structure of the hot-gas specimen. Iterative procedures have proven useful for solving the equations. The solutions are independent of spectroscopic resolving power, as long as all measurements at a given wave length are made with the same optical conditions.

Infrared emission-and-absorption spectra of hot gases having known temperature profiles were measured, in order to evaluate methods for solving the spectral-emittance equations in practical cases. In these experiments, controlled inhomogeneous gas specimens were produced by two methods. In the first method, a series of porous plug burners were placed in line, each at a different temperature. In the second method, several quartz gas cells were lined up in a differential electric furnace. In either case, spectroscopic measurements could be made along a line of sight through the controlled inhomogeneous gas path. The temperature of each zone was measured independently, by the infrared emission-absorption technique. Spectral emission-absorption temperatures were determined from the spectral data at several wave lengths, using the Kirchoff and Planck laws. The results for isothermal gases were independent of wave length, as expected from theory. The results for a simple nonisothermal case--a temperature discontinuity in an otherwise uniform temperature profile--provided a measure of the extent to which the spectrum of a gas is affected by thermal gradients. Spectra of more complex gas systems are currently under study. ★

sunspot cycle and ionospheric storms

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

The ham radio operator has probably noticed that reception in the 10-to-30-meter band has recently (December 1964) not been nearly as good as it was 5 or 6 years ago. But he has also probably noticed that he is able to work more distant stations in the 60-to-100-meter region.

This is because we are now in the low sunspot period of the 11-year solar cycle. Ionospheric electron density decreases during periods of low sunspot number, and increases when the sunspot number is high. High-frequency radiation (3 and 30 Mcps, 10 to 100 meters) is particularly sensitive to electron-density variations. As electron density increases, the HF band opens up with more useable frequencies toward the higher end. But at the same time there is a slight contraction of the useable frequencies at the low end of the band. On balance, however, the spread of useful frequencies is greatest with high electron densities. Ionospheric effects on HF propagation are well known. They are the bases for the monthly charts published for the ham operator which show optimum frequencies for a given time period and propagation path.

In a study recently completed at AFCRL by Raymond J. Cormier and TSgt. Kenneth L. Smallwood, diurnal and seasonal ionospheric influences on HF propagation are examined in relation to still another influence--ionospheric storms. The study, "Sunspot Cycle and Ionospheric Storms," is based on an analysis of the amplitudes of signals received at the AFCRL site in Concord, Mass. The signals were transmitted from WWV at Beltsville, Maryland, a path of 590 kilometers. Recordings made in 1960, a year of moderate sunspot number, were compared with recordings made in 1963, a year of low sunspot number. The findings of the study relate only to a north-south mid-latitude path.

The term, "ionospheric storm," is inherently misleading. We are not necessarily talking about some great turbulent condition of ionized particles in the ionosphere. The usual ionospheric storm is simply a condition in which there is a marked reduction of free electrons in the ionosphere. This depletion is induced by geomagnetic disturbances. In 1960, there were 40 such disturbances reported and observed at the AFCRL Concord site with magnetic AK values 30 or above. In 1963, there were only 15 such disturbances.

Although there is a greater spread of useable frequencies during the active sunspot cycle, communications are subject to more interruptions due to the greater number of magnetic disturbances.

The continuous variation in ionospheric electron density results in the continuous expansion and contraction of the useful HF spectrum. This is brought about by processes of absorption and reflection of the HF signal. The shorter the wave length, the deeper it penetrates into the ionosphere. Without a relatively heavy electron layer in the F_2 region, shorter wave lengths will pass completely through the ionosphere and continue on into space. At the other end of the spectrum--100 meters or so--where the D-layer is the primary influence, the longer wave lengths are absorbed. But the thing to remember is that the contraction of the useable low frequencies, due to high electron concentrations, is much less than the expansion of useable frequencies at the high end of the spectrum. The upper and lower limits of the HF spectrum, useable at any given time, are known respectively as the Maximum Useable Frequency (MUF) and the Lowest Useable Frequency (LUF).

With this as background, let's look at some of the results of the AFCRL study of sunspot cycle and ionospheric storms. The study uncovered several characteristics of ionospheric storms as these storms affect HF propagation.

The study shows that, during the moderately active sunspot year of 1960, average magnetic disturbances had a quicker and longer-lasting effect on the MUF than did disturbances during the quieter year of 1963. In 1960, the chain of cause-and-effect events (magnetic disturbance-ionospheric storm-lowered MUF) brought about the greatest reduction in the MUF on the day the magnetic disturbance occurred. In 1963, the greatest reduction of the MUF occurred a day later. But in 1963, the MUF effect was of shorter duration. Curiously, there was no parallel pattern for the LUF. The onset, intensity, and duration of the LUF changes were the same for both years studied.

Because, in general, the 1960 magnetic disturbances were more intense, the results with respect to the MUF variations suggest that the onset, magnitude, and duration of an ionospheric storm are governed by the intensity of the magnetic disturbance. It was also found that the time of day at which the disturbance occurs is a contributing factor.

Another finding, one not directly related to ionospheric storms, is that, during the period of low sunspot number, the normal seasonal variations of the MUF (hence, seasonal variations of electron densities of the F_2 layer) are not as great as the variations during the period of moderate sunspot number.

The study may contribute to the precision and usefulness of AFCRL's Index of Ionospheric Storminess, an Index developed several years ago which provides a guide to the lowest useable frequency and the highest useable frequency that can be employed to send a signal of a given amplitude over a particular propagation path. ★

SPORADIC E NOT SO SPORADIC AFTER ALL

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

If you have just read the above item on "Sunspot Cycle and Ionospheric Storms" you may have been left with the impression that, although the ionosphere is highly sensitive to various influences, there appear to be some simple cause-and-effect relationships. Therefore, with precise measurements and interpretation, we can account for--and perhaps predict--ionospheric change.

The item ignores sporadic E. Sporadic-E layers are large, concentrated patches of ions in the E region. These ionized layers affect high-frequency communications, most often unfavorably.

Just how these concentrated ion patches come about has been a problem for some time. It has been suggested that wind shear in the neutral gas of the E region can produce sufficient ion transport to account for some occurrences of sporadic E. Dr. Norman W. Rosenberg of AFCRL recently carried out observations of winds and sporadic E in the E region that tend to confirm this hypothesis. This confirmation is a by-product of his research involving the release of luminous chemical trails by rockets at altitudes between 90 and 150 km.

Simultaneously with the observations of the luminous trails, ionosonde measurements of the maximum frequency reflected from ion layers were made. From these measurements the presence or absence of sporadic E was determined. The luminous trail itself showed that upper-atmosphere winds change direction with altitude with surprising regularity. Rosenberg found that wind direction generally changed continuously in a clockwise manner (viewed from above) as altitude increased.

How is this wind fluctuation related to sporadic E? The rate at which wind changes direction with altitude is called wind shear. If wind direction varies greatly within a relatively small distance in altitude, the wind shear is large. Sporadic E seems to be related to east-west wind shears--specifically, to maximum negative east-west wind

shears where a west wind is directly above an east wind. During Rosenberg's observations of upper-atmosphere winds, the ionosondes recorded 10 occurrences of sporadic E within the altitude range where winds were measured. Of these 10, 7 occurred within 2 km of maximum negative east-west wind shears. (2 km is about the margin of error in determining the altitude of an ion layer by ionosonde, so that this proximity represents a significant correlation.) Rosenberg reported this correlation in the July 1, 1964 issue of the Journal of Geophysical Research. Since that time, rechecking of the data has shown the correlation to be even better than was reported.

The explanation for this correlation is as follows: since any charged particle moving through a magnetic field is acted on by a force which is perpendicular to both its direction of motion and the magnetic lines of force (except when the direction of motion parallels the lines of force), the charged particles carried along by ionospheric winds are pushed vertically (up or down) by the earth's magnetic field. The force it exerts on them is a maximum if they are travelling in an east-west direction. In the case of positive ions, those travelling with a west wind will be pushed downward, while those travelling with an east wind will be pushed upward. Thus, if there is a west wind directly above an east wind--a maximum negative east-west wind shear--positive ions will tend to collect between the two winds, forming a localized layer of high ion density. Because sporadic E occurs near maximum negative east-west wind shears, Rosenberg believes that the above process may account for its occurrence. ★

SCIENTIFIC NOTES

Low-Loss Acoustic Bonds: In just about any device you must somewhere along the line couple one part to another. Where energy is transferred between these parts, you want to transfer this energy with minimum loss. In transferring electrical energy, losses are minimum. This is not true in transferring acoustic waves at microwave frequencies. At the point where parts join, sizeable losses can occur. If the potential of new classes of compact microwave devices now evolving is to realized, such losses must be minimized. Losses occur where the bond is thick relative to the acoustic wave length. For minimum attenuation, the thickness of the bond should be much smaller than the acoustic wave length. By conventional bonding methods, this is not possible to achieve. Using the well-known fact that two highly polished materials will cling together with great force, AFCRL has worked out techniques for the "cold welding" of surfaces. The term, optical contact bond, is given to the technique because the thickness of the bond is measured in terms of the wave length of light. The thickness of the AFCRL bond is only about one tenth to one twentieth of the wave length of light. With optical bonding, acoustic waves at microwave frequencies have been transferred between two parts with losses of less than one per cent. (Microwave Physics Laboratory, AFCRL)

Gemini Rocket Support: AFCRL has been asked to provide 10 high-altitude rocket launches at Cape Kennedy in connection with the Gemini vehicle launches. The SIDEWINDER-ARCAS combination will carry a 12-pound nose cone to an altitude of about 400,000 feet. The rocket flights will be used to provide temperature, atmospheric-density, and wind-velocity information needed for precise knowledge of the atmospheric parameters during launch of the Gemini package. When the second-stage ARCAS reaches apogee, a 3- or 5-foot spherical balloon will be ejected. This balloon (to be designated ROBIN) will be made of thin plastic with a metallic coating to permit radar tracking. From the path of the balloon, the wind velocity, wind direction, atmospheric density and other data will be derived. The SIDEWINDER-ARCAS combination is being developed for AFCRL by the U.S. Naval Missile Center, Point Mugu, California. (Aerospace Instrumentation Laboratory, AFCRL) ★

the ACM-ACMCP concept a computer-oriented chemical nomenclature

DR. LEONARD SPIALTER
Chemistry Research Laboratory, ARL

In an era of explosively rapid advance and expansion of scientific knowledge on all fronts, one of the most serious factors severely limiting the efficient storage and utilization of chemical information is the incompatibility of current molecular-structure pictographic diagrams and nonuniform multilingual nomenclature with modern computer techniques and high-speed memory devices. While such diagrams and terminology are suitable for teaching purposes and small-scale manual sorting, it is already obvious that they are not efficient even in limited literature searching. Moreover, the difficulties may be expected to increase very rapidly with time as quantity and complexity increase in the literature.

This problem, at least with respect to the indexing of chemical structures, has been recognized and, during the past decade, attempts have been made to cope with it. However, these have been dependent on various empirical, nonsystematic, heterogeneous, and subjective ad hoc coding according to functional groups, empirical formulae, chemical name, structure classification, ordering based on the alphabet, atomic number, frequency of occurrence and other schemes, as well as complex combinations of these appearing in recent line-formula notations (eg. Dyson, Wiswesser, etc.) These latter, however, suffer from a multiplicity of rules involving not only priority but also specialized group symbolism which requires deciphering tables for interpretation. Moreover, they are inflexible and unrelated to current and future changing theories of molecular structure and reactivity, and no more information can be retrieved from them than was initially selected for encoding from the original molecular formula. The magnitude of this latter limitation is a function of the breadth of interest and the perspicacity of the professional chemist required for this activity.

Recently, the author has devised a computer-oriented symbolism, based on two (or, at most, three) simple rules requiring minimal or no significant chemical or mathematical knowledge, which is the analog of the chemical pictograph or equation of a molecule or reaction. The symbolism has a one-to-one correspondence with its pictorial progenitor independent of orientation, nomenclature, language, or numbering order, and can accommodate any structure which can be drawn if the complexity of the resulting expression (in certain cases) is acceptable. This means that the same answers may be obtained from the analog as from the initial pictorial representation.

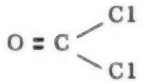
THE ACM

The core of this new symbolism is the Atom Connectivity Matrix, or ACM. This is a matrix array composed of mathematical elements a_{ij}, where i and j are integers defining the row and column at whose intersection a_{ij} is situated. In the diagonal elements, where $i = j$, are placed symbols for the atoms, radicals, electrons, charges, or other constituent groups making up the molecular formula. Order of assignment is unimportant. In the respective off-diagonal positions, a_{ij}, where $i \neq j$, are placed the "connectivity" (bond order, energy, force constant, directional cosines, or any other bond parameter) between the atom at a_{ii} and that at a_{jj}.

In most cases, bond-order values of 0, 1, 2, and 3, to describe classical zero, single, double and triple bonds, respectively, between two atoms or groups have proven to be the most useful "connectivity" parameters.

As illustrative examples of ACM's, we may cite the following for the given molecular structures:

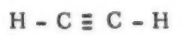
Molecule



ACM

C	2	1	1
2	θ	0	0
1	0	Cl	0
1	0	0	Cl

(where θ is used instead of 0 for oxygen in order to eliminate confusion with zero)



H	1	0	0
1	C	3	0
0	3	C	1
0	0	1	H

It is to be noted that the ACM for large molecules may appear as a formidable array; nevertheless, this is not as bad as first glance might indicate because most of the off-diagonal elements are zero owing to the fact that, in a given row or column, the sum of the numerical values of all such elements must equal the total connectivity (or valency) of the atom in the diagonal element. Commonly, this is a small number not exceeding a value of 4.

However, it is possible to effect a significant saving in the size of the ACM by noting that its greatest application will probably be to organic molecules, both by virtue of their overwhelming volume in the literature as well as their large numbers of isomers. Since hydrogen atoms, except in less common molecules such as perhalocarbons and others of similar nature, constitute a large proportion of the atoms in most organic structures (more than two thirds in the case of the paraffinic hydrocarbons), and since their bond-order connectivity has a value of unity (i.e., such atoms are not involved in the molecular backbone), it has been found possible and convenient to omit them from the ACM when hydrogenations are omitted from the molecular pictograph and/or from the ACM. The author has referred to this as the "hydrogen-suppressed" case.

The ACMCP

It may appear, at this point, that the ACM is not unique in that a molecule such as fluorochlorobromoiodomethane can lead to as many as 120 different-looking ACM's depending upon which permutation in the order of the constituent atoms is taken to fill the diagonal elements.

However, no matter how different the ACM's may seem to be, it is the most important identifying attribute of all ACM's for a given molecule that their characteristic polynomials (ACMCP) are identical. This ACMCP, obtained by evaluating the matrix as a determinant, can be shown to be an invariant for a given atomic connectivity system. It is independent of chemical nomenclature, atom-numbering conventions, ring indices and orientation or dimensions of the original molecular pictograph. It is a function only of the atoms or groups and their interconnectivities as shown in the pictograph.

For some of the complete molecules (i.e., those whose ACM's contain all constituent atoms), we have the following ACMCP's:

Molecule	
phosgene	$COCl^2$-2ClO-3Cl
acetylene	C^2H^2-2CH-$9H^2$+1
fluorochloro-bromoiodomethane	CFClBrI-FClBr-FClI-FBrI-ClBrI

Only simple examples have been shown, but the invariancy of the ACMCP is general.

Moreover, the number of separate terms in the ACMCP never exceeds the number of atoms in the original structure upon which the ACM was based and, frequently, it can be much smaller because of symmetry considerations.

It is to be noted that the first term of the ACMCP is the molecular formula, in the French notation where superscripts are used instead of subscripts, when all of the constituent atoms are placed into the ACM. This then leads to the obvious corollary that the formula index of a molecule represents the lowest-order approximation to the ACMCP, and that tabulations of ACMCP's are compatible with formula indices, such as those of Chemical Abstracts, Chemisches Zentralblatt, etc.

In principle, any molecular pictograph and all of its accompanying data relating to atoms and bonds can be stored in the ACM. The ACM is an equivalent mathematical analog, and the same questions may be asked of it as are asked of the pictograph. In essence, how the chemist draws the original molecule, its atoms and their connectivities determines also the ACM and its relative order of approximation.

In recent papers, cited at the end of this report, the author describes in greater detail, with examples, the ACM-ACMCP concept, and analyzes the physicogeometric significance of the various terms of the ACMCP.

Further extensions to stereochemistry and analogs to chemical reactions have been made, and it is planned to publish these results shortly. ★

REFERENCES

(1) *"The Atom Connectivity Matrix (ACM) and its Characteristic Polynomial (ACMCP): A New Computer-Oriented Chemical Nomenclature," Journal of American Chemical Society, 85, 2012, 1963.*

(2) *"The Atom Connectivity Matrix (ACM) and its Characteristic Polynomial (ACMCP)," Journal of Chemical Documentation, 4, 269-274, 1964.*

(3) *"The Atom Connectivity Matrix Characteristic Polynomial (ACMCP) and its Physicogeometric (Topological) Significance," Journal of Chemical Documentation, 4, 261-269, 1964.*

photographic-reconnaissance BALLOON FLIGHT

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

A 1.6-million-cubic-foot balloon designed by the Air Force Cambridge Research Laboratories was launched from Holloman Air Force Base, New Mexico, on 29 October 1964, on a photo-reconnaissance experiment to determine the amount of distortion in photographic images at various altitudes high above the earth.

A specially developed high-acuity camera, six feet in length and equipped with a high-resolution lens, was installed and stabilized in the balloon gondola. Flying beneath the balloon was an RB-57 reconnaissance plane on which was painted a variety of stark geometric patterns. The experiment was conducted for the Aeronautical Systems Division, Air Force Systems Command.

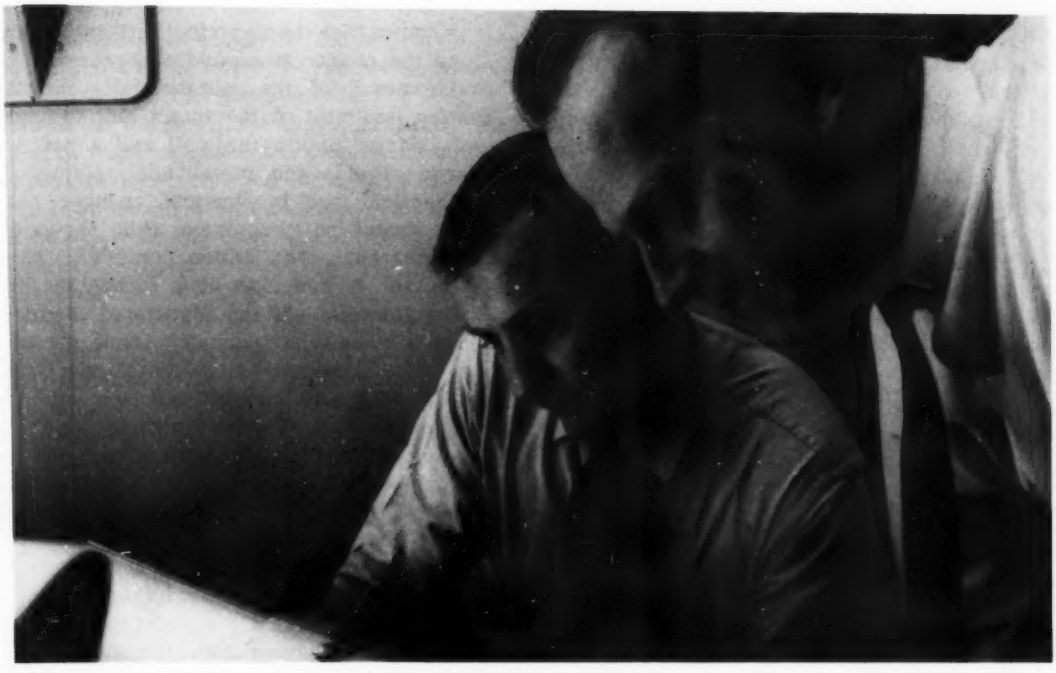
The RB-57 was painted on its upper surface in black-and-white patterns arranged as bars, circles and lines, and rectangles to afford images with sharp contrast. The patterns permitted scientists to define photographically confusing effects caused by natural air turbulence. Two areas of turbulence were of special interest: ground thermal effects occurring 50 to 500 feet above the ground, and effects caused by the jet stream at about 35,000 feet. As one of a planned series of projected flights and balloon-launched photo studies, this mission high over the White Sands Missile Range included many individual passes under the camera by the RB-57.

The balloon was launched under the direction of Lt. Col. Michael S. Kretow of AFCRL. Reaching a peak altitude of 80,000 feet some 2 hours after launch, it hovered at several different altitudes during the aircraft passes and was brought down in the afternoon on the range by command signals controlled from the balloon-control center. Recovery crews, sent ahead of time to the predicted area of landing, quickly closed in on the grounded gondola and retrieved both it and its entire pay load. ★

OAR PROFILES

Dr. Carl W. Kreitzberg, a research physicist with the Satellite Meteorology Branch, Meteorology Laboratory, AFCRL, writes in this issue of the Review on his "Project Stormy Spring." He is currently using the subsynoptic and mesoscale radiosonde data from this project to diagnose the trajectories and dynamics associated with cloud-system development. The objective is to improve the dynamical interpretation of satellite cloud data, and to examine the 24-hour predictability of clouds. Dr. Kreitzberg has a B.S. in Meteorology (1959) from the University of Washington, Seattle, Washington. He received his Ph.D. in 1963. He belongs to the American Meteorological Society, and has several publications to his credit.

Captain William B. Goggins, Jr., is an engineer with the Microwave Physics Laboratory, AFCRL. He was graduated from the U.S. Naval Academy in 1957. He also has an M.S. Degree in Electrical Engineering from the Air Force Institute of Technology, Wright-Patterson AFB, Ohio. In this issue of the Review, his current work is described in the article, "An Ultrastable Microwave Radiometer."



The article, "Sunspot Cycle and Ionospheric Storms," which appears in this issue of the Review, reports the work of Mr. Raymond J. Cormier and TSgt Kenneth L. Smallwood, both of the Upper Atmosphere Physics Laboratory, AFCRL. Mr. Cormier is a research physicist with the Ionospheric Properties Branch of the Upper Atmosphere Physics Laboratory. He has a B.S. degree in Physics from the University of Massachusetts (1959), and has several publications to his credit. Currently, he is working on HF ionospheric propagation. TSgt Smallwood is an electronic and data technician with the Upper Atmosphere Physics Laboratory. He completed electronic technical training at Keesler AFB, Miss., in 1954, and advanced electronic training at Scott AFB, Ill., in 1957. TSgt Smallwood is shown on the left, and Mr. Cormier on the right.

Dr. Leonard Spialter has been a research chemist with the Chemistry Research Laboratory, ARL, from 1951 to the present. He has a B.S. in Chemistry from Rutgers University (1944), an M.S. in Synthetic Organic Chemistry from the Polytechnic Institute of Brooklyn (1947), and a Ph.D. in Physical-Organic Chemistry from Rutgers (1949). He also has done postdoctoral work at Harvard from 1949-1951. Currently, Dr. Spialter is working on the preparation and properties of perarylated silane compounds and polymers, and the development of a new computer-oriented chemical nomenclature. He has a great number of publications to his credit. In this issue of the Review, Dr. Spialter writes on "The ACM-ACMCP Concept--A Computer-Oriented Chemical Nomenclature."

"ACT FROM THOUGHT SHOULD QUICKLY FOLLOW"*

(initiation of muscular contraction)

CAPTAIN JOEL R. LOWENTHAL
Directorate of Life Sciences, AFOSR

A subject of long-standing interest to neurophysiologists is the mechanism by which thoughts arising in the brain are converted into muscular contraction in the periphery. An exact physiological definition of a thought is obviously beyond the scope of this article, since it is still beyond the scope of scientific knowledge. Once a thought occurs, however, it is generally accepted that a command to the muscles is conveyed from the brain in the form of a nerve impulse. The path that this impulse travels is the fundamental unit of the nervous system, the neuron or nerve cell.

The conduction of electrical impulses along the neuronal membrane has been well studied. It is known that the electrical activity passing along the neuron is a wave of depolarization or reversal of the metabolically induced resting potential of the intact cell (a negative charge inside the cell and a positive charge outside the membrane). Numerous biochemical and biophysical changes have been shown to accompany this spreading depolarization, or "action potential," as it is called. It has also been found that this action potential and the associated chemical changes travel peripherally from the cell body of the neuron to the distal end of the axon. When this wave arrives at the presynaptic side of a neuromuscular junction, it releases from the axon terminal a chemical transmitter, acetylcholine, which somehow initiates the contraction of the adjacent muscle fiber.

Although the neuronal ending appears to end directly on the individual muscle fiber, there is actually a definite and very constant gap of about 200 microns between the membrane of the neuron and the membrane of the muscle cell. The fact that such a constant gap exists prompted early investigators to hypothesize a transmitter agent in the first place--a substance which might conduct messages across the "sea" of extracellular fluid separating the two cells. Thus does science progress: first a hypothesis, and later actual isolation and purification of the transmitter.

Prof. Stephen Thesleff, an AFOSR grantee at the University of Lund in Sweden, has been working on the problem of neuromuscular transmission by studying the effects of acetylcholine on the mammalian motor endplate (the specialized area of the muscle-cell membrane where the neuron terminates). The theory has been advanced by workers in this area that acetylcholine is released from the nerve endings in discrete quantitative packets or quanta, and that a certain minimum number of quanta must be released and transmitted across the neuromuscular junction in order to activate the muscle to contract. Thesleff and his associates have inserted microelectrodes inside the muscle cells and made direct measurements of potentials in the motor-endplate area. By varying the parameters of the

*Auden, Wystan Hugh, "On This Island," (XXII), From John Bartell's Familiar Quotations, (13th ed.), Boston: Little, Brown and Company, 1955, p. 993.

electric stimulus applied to the prejunctional neuron, and by employing certain drugs known to interfere with the synthesis of acetylcholine in the neuron endings, Thesleff was able to make important observations on the effects of these changes on endplate potential and "obtain a mathematical expression from which the quantum size and the quantum content of the endplate potential could be calculated."

Important applications of this work are not difficult to find. Understanding the release of chemical transmitters by a nerve impulse, and also the subsequent mechanical contraction of the associated muscle fiber is an important step in the development of energy-transformation systems. Indeed, the direct conversion of chemical energy to mechanical energy in the neuromuscular unit is a striking example of an energy-transformation system that has not yet been exploited in modern technology. An accurate description of the mechanism of action of intraneuronal and neuromuscular junctions will also add to our knowledge of neural networks, signal controls, and information processing.

An added by-product of this research is in the field of medicine, where it provides a better understanding of the not-so-uncommon disease, myasthenia gravis. Patients afflicted with this illness have a defect in the initiation of muscular contraction by nerve impulses. They are consequently handicapped with disabling muscular weakness or paralysis. Prof. Thesleff and others have studied muscle specimens from patients with this ailment. The activity of the motor endplate has been demonstrated to be intact, and the defect seems to be on the neuronal side of the gap. Thesleff has concluded from his studies that there is a reduction in the rate of mobilization and release of the transmitter substance from the terminal nerve fibers. Why this is so is not yet known; but it is not at all unlikely that the ultimate solution of this question will bring with it better treatment than is now available, and perhaps a cure for this disabling disease. ★

an ultrastable microwave radiometer

MICROWAVE PHYSICS LAB., AFCRL

A radiometer is essentially any detector of electromagnetic radiation. One type of radiometer is used to measure the characteristics and strength of radio signals and background noise. It is a basic element of radio telescopes, and is used by the antenna engineer to evaluate antenna performance.

Masers or parametric amplifiers are now standard components in radiometers. But the big jump in sensitivity provided by these new amplifiers has not been achieved without cost. The cost is a continuous, unpredictable drift in gain. Unless the equipment is closely monitored, there is no way of knowing whether the variations in the strength of the recorded signal are real or are due to the equipment.

The gain-drift problem in radiometers has been eliminated in a new type of radiometer designed by Captain William B. Goggins of AFCRL. The radiometer has proven to be absolutely stable. This stability is achieved by a very simple principle. A motor-driven variable attenuator is used to continuously vary a reference noise source in order to balance the incoming noise signal. In this way, gain-drift effects in the active components of the radiometer are eliminated.

This absolute stability permits the radiometer to be operated automatically. It can be turned on and off with a time clock. In the particular model built and evaluated at AFCRL, it has not been necessary to calibrate the radiometer except when components are changed. These advantages can result in a great savings in man-hours used to monitor the radiometer and process the data.

The radiometer has been used for the past several months in a test program associated with AFCRL's experimental multiplate antenna. The reliability of the radiometer data has speeded up this testing program significantly. Few patterns were lost due to radiometer failures, and it was not necessary to make large numbers of patterns to insure data reliability. ★

MEASURES FOR MEDITATION, OR, CAN WE QUANTITATIVELY DESCRIBE AND PREDICT HUMAN PERFORMANCE?

ROWENA SWANSON
Directorate of Information Sciences, AFOSR

While the neurophysiologists and the biophysicists examine the structure and performance of biological systems, the biochemists study the characteristics and changes in large molecules, and the mathematicians and philosophers construct models of dynamic systems, the societies which will benefit from the results of these endeavors function with the tools they have, and try to perfect the use of their immediately accessible resources. Is it a paradox that we find, in this age of technology and machines, that our most valuable resource is man? What are the characteristics of this resource? Can we learn enough about him from the observation of his behavior as a total system, as a subsystem within larger systems, and from what he says about himself to perfect him for himself and for the societies in which he lives? These are some of the inquiries of the psychologist, the psychiatrist, and the behavioral scientist.

A small portion of these inquiries concern us in the Directorate of Information Sciences, AFOSR. We want to know how man receives information, what forms are most acceptable and useful to him, how he processes information, and how he can improve his methods of processing. We want to know how man functions as a communication channel, and how man uses what he receives. The behavioral scientist tells us these are not easy items to discover; and they are, moreover, dependent on factors which can vary from man to man. Is it possible, then, to develop measures for man that accord with scientific objectivity?

Any teaching or training procedure, in effect, assumes a set of criteria related to the ability of man to perform. The parent teaching the child to walk, the professor expounding to the student, the commander issuing orders--all these are based on tacit hypotheses of methodologies for transmitting information. Are these the best ways? How does one compare one approach with another? How does one measure the ability to learn? How does one measure the action potential of man? How is this converted to kinetics?

In one of many laboratories probing man, AFOSR has been sponsoring a study of measures which might assist us in predicting characteristics of performance. This study is concerned primarily with the behavior of scientists and their environments; but subjects have ranged from scientists in research centers to talented high-school students on summer science projects. Only one small phase of the study has been completed. Results are not as conclusive as the project leader, Dr. Calvin W. Taylor of the University of Utah, might have wished. Why, then, report on it? Because the results do not demonstrate the fallacy of this approach, but indicate the complexities which are involved and must be known and appreciated if ultimate goals are to be achieved.

Dr. Taylor and his co-workers have provided us with studies that bear examination. Among these is an investigation of communication abilities in military situations, (1) predictors for scientific productivity and effectiveness, (2) and bases for a theory of education. (3) A recent volume, Creativity: Progress and Potential, summarizes the current knowledge of Dr. Taylor and others and suggests areas of urgent research needs. (4) Under NSF sponsorship, Dr. Taylor found that many of the creative and productive characteristics exhibited by mature scientists were measurable in samples of high-school students but, significantly, in students engaged in research projects, not in academic environments. The completed phase of Dr. Taylor's current study, referred to above, extended test batteries on new student samples. Dr. Taylor summarizes some of his results as follows:

"The results verified the notion that char-

acteristics found in adult scientists can be differentiated in adolescent-age youngsters. However, individual predictor scores which had previously been found to be the most significant were not the ones which worked the best in the present study. Previously, our Biographical Information Inventory (BII) had been our top instrument, followed by the Self-Description Rating Form, the Satisfactory Achievement Scale, the National Merit Scholarship Corporation Form, and some pencil and paper Aptitude Tests, in that order. In the present study, the Aptitude Tests were the best single predictor of research performance." (5)

He follows this report with the following critical statements: "Much of the change was considered to be the result of difficulty in securing the criterion information. Many of the criterion forms were not filled out properly by the supervisors, leaving us with data of questionable reliability. .... In fact, we had some evidence to suggest that the biographical information inventory was much more stable than the criteria."

It might be well, from this, to reflect a bit on tests given to various groups for various purposes, on the situations and contexts in which they are given, on the relevance of results to criteria, and on the classification and assignment of people on the basis of test scores. We do not subscribe to random assignments. Test batteries are predictors; but they are as sensitive to environment as is a chemical balance. Like any other instrument, they can be improved. If Dr. Taylor's research makes us aware of how much improvement is needed, this should not cause discomfort, but should be a spur toward improvement. When we know what we don't know, we are at least on the road to knowledge.

Addendum

The reader may want to apply one of Dr. Taylor's tests to himself. The following pertains to aspects of creative ability. Where do you fit?

Rating Scale F

1. Subject hardly ever has an idea of his own, and never thinks of modifying an accepted method even if it doesn't fit the situation.

2. Subject usually thinks only of standardized or routine approaches, doesn't have much imagination, and seldom contributes new ideas.

3. Subject generally does not contribute his own ideas to a new problem and frequently needs the advice of co-workers. Occasionally has an original idea, but usually it is of minor significance.

4. Subject's ideas often contain some germ of novelty, but are mostly familiar or conventional. Has occasionally devised an improved method or piece of equipment; conducts an investigation on his own with about average ability.

5. Subject contributes more ideas to the work than does the average worker, is inclined to raise questions, and enjoys speculating about alternative courses of action. His suggestions usually are good ones.

6. Subject has lots of ingenious ideas. Left alone, he would keep continuously busy trying them out. Often points out applications of his own results to other problems or fields; calls attention to uses of a technique beyond its original purpose.

7. Subject has exceptional capacity for devising original approaches to problems. He is one of the most creative students in this program. ★

REFERENCES:

(1) Taylor, Calvin W., William R. Smith, Brewster Ghiselin, Boyd V. Sheets, and John R. Cochran, "Identification of Communication Abilities in Military Situations," WADC-TR-58-92, AD 151043, AF 18(600)-1211, June 1958.

(2) Taylor, Calvin W., William R. Smith, Brewster Ghiselin, and Robert Ellison, "Explorations in the Measurement and Prediction of Contributions of One Sample of Scientists," ASD-TR-61-96, AF 41(657)-158, April 1961.

(3) Taylor, Calvin W., Brewster Ghiselin, John A.

Wolfer, Lorraine Loy, and Lyle E. Bourne, Jr., "Development of a Theory of Education From Psychological and Other Basic-Research Findings," HEW Office of Education Proj. No. 621, August 1964.

(4) Taylor, Calvin W., ed., Creativity: Progress and Potential, New York: McGraw-Hill Book Co., 1964.

(5) Taylor, Calvin W., Elwin Nielsen, Gary M. Cooley, and Robert Ellison, "Identifying Research Characteristics in High-School Students-- A Second Study," AF-AFOSR-11-63, August 1964. (Available from DDC)

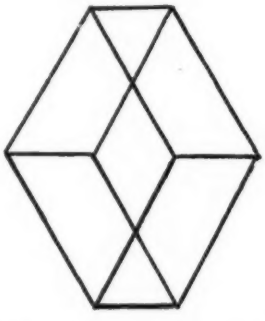
PERCEPTION IN THE WORLD OF SPACE

DR. ROBERT E. ADAMSON
Directorate of Life Sciences, AFOSR

The term, "perceptual constancy," refers to the recognition of objects as they are--that is, maintaining appropriate size and shape, even though the corresponding size and shape of the retinal image of the object changes with distance and the orientation of the observer. It is likely that such constancies develop partly as a product of early learning, and that they represent a complex form of information processing utilizing multisensory feedback coupled with experiential cues. One implication of this is that they depend upon a familiar world, one in which objects do not hang in space, where the sun casts reliable shadows, and we know what is "up" or "down."

The constancies certainly constitute the primary, and possibly the only, mechanism for maintaining appropriate relations to our environment. One can imagine the chaos which would result if perception were determined solely by sense receptors: our world would be peopled by giants and midgets changing into one another; shapes would be elastic, squares changing into trapezoids, circles into ovals, etc., as objects moved relative to the observer. Such would be a world without a frame of reference, one lacking the familiar cues which allow veridical perception.

And such may be the world of space. As part of a larger program concerning perceptual mechanisms (supported by grant AF-EOAR 93-63), Dr. Richard Gregory, of the Psychological Laboratory, University of Cambridge, participant in the 1964 Cloudcroft Symposium, has simulated some of the conditions to be expected in space. In one study,[1] subjects are transported on an electric railway through total darkness past luminous three-dimensional models of conventional shapes. Compelling visual illusions result, which persist, regardless of familiarity with the situation. Objects turn themselves inside out and undergo transformations which render them unrecognizable. Furthermore, in the case of latticework objects, such as the following, reversals of far and near sides are frequent, making it difficult to ascertain part relationships.



Such illusions represent a breakdown of perceptual constancy or, more generally, a breakdown in man's ability to relate himself to his surroundings. Conditions in space, as Dr. Gregory points out, favor such a breakdown and may lead to difficulties in approximating distance and scale (for example, on the moon); in assembling parts of prefabricated space stations, particularly if they are lattice structures; and of recognizing unfamiliar objects with any exactitude. In Dr. Gregory's words: "The space traveler, then, will see new worlds, and perhaps new life forms through perceptual filters adapted to objects on earth." This may occasion severe problems for successful operation, unless artificially structured familiar cues to perception are devised to assist the space traveler. ★

(1) "Visual Illusions in Space," New Scientist, Vol. 1, 1963, pp. 446-449.

LUNAR GEODESY... A PROBLEM IN STATISTICS

MAHLON HUNT
Terrestrial Sciences Laboratory
AFCRL

Making an accurate map of the moon would seem a rather simple job. After all, a good high-resolution photograph of the moon provides much detail. But, from the standpoint of the lunar geodesist (selenodesist), current lunar maps are not very good. They do not provide a reliable basis for measuring distance between two points on the surface of the moon, even though, with our best telescopes, craters on the lunar disk can be photographed to within about one half mile in diameter.

There are several reasons for this. Distortions are introduced onto the photographic record by atmospheric turbulence and refraction. Two photographs of the moon taken with the same telescope where seeing conditions are excellent (absence of turbulence) may show differences in distances of several miles from one reference point on the moon to another. The optics of the telescope itself may introduce distortions. Angular inaccuracies in arc seconds on earth translate to thousands of feet when extended to earth-moon distances. Another reason is the libration, or wobbling, of the moon. The moon wobbles over a range of seven and a half degrees each lunar month.

Within the past year, a group in AFCRL's Terrestrial Sciences Laboratory has been giving increasing attention to the specialized field of lunar geodesy. The goal of the AFCRL program is to establish a standard network of horizontal and vertical lunar control necessary for precise lunar cartography. By "control" is meant the establishment of reference points, the distances between which are known with great accuracy.

The research itself is grounded in statistics and photogrammetry. What it involves, as a first step, is the examination of hundreds of photographic plates, plates from observatories all over the world and extending back to the 1890's. Glass plates rather than film are used wherever possible because the film itself introduces distortions. Greater accuracy is obtained if the exact date and time of the photographic record are known--as well as the point of the libration cycle. With respect to physical libration observations, the most extensive data have been acquired by the Russians.

AFCRL selenodesists have developed a statistical method for obtaining lunar control points in which the various error-inducing mechanisms are taken into account. The method is being tested with various sets of measured observations using high-resolution photographic glass plates. The complexity of factors involved in the approach forces the group to rely strongly on computers for analysis.

The Ranger 7 photographs will be studied in detail as a part of this effort. But at best they can provide only a single datum point in an over-all study leading to a control network involving hundreds--or thousands--of such points. ★

zero-phonon lines and phonon coupling in spectra of ZnS:Mn crystals*

DR. D. W. J. LANGER
Solid State Physics
Research Laboratory, ARL

The II-VI compounds are receiving increasing interest for components in solid-state devices for both military and civilian applications. The properties of these compounds are greatly affected by impurities. Much of the research at the Solid State Physics Research Laboratory at ARL is concerned with determining the effects of impurities in single crystals of the II-VI compounds and explaining these effects in terms of physical or mathematical models.

Manganese is an efficient luminescence activator in a number of crystals, e.g., silicates, sulfides and fluorides of zinc and cadmium. One important characteristic of the manganese activation is that the emitted light is concentrated in a spectral band of 200Å halfwidth, (with a maximum in ZnS at about 5860 Å). This halfwidth is much narrower than that of the emission activated by Cu or Ag but, on the other hand, is much wider than that observed in the luminescence of rare-earth activated crystals. A second important characteristic is that absorption measurements on crystals containing Mn usually show several absorption bands at energies above the Mn-emission band. For ZnS, Kroeger (1) showed that the existence of four absorption maxima and a fifth band with a smaller absorption coefficient is also well known (Fig. b).

It was postulated early that these processes must be due to electronic transitions within the manganese which, as a divalent ion, could readily occupy the site of Zn^{2+} in the ZnS lattice. The behavior of the Mn^{2+} states in a cubic crystalline field can be estimated from the calculations of Sugano and Tanabe (2) (see Fig. a). Quantitatively, however, the agreement with observation has not been too good, and the level assignments of higher bands has been dubious.

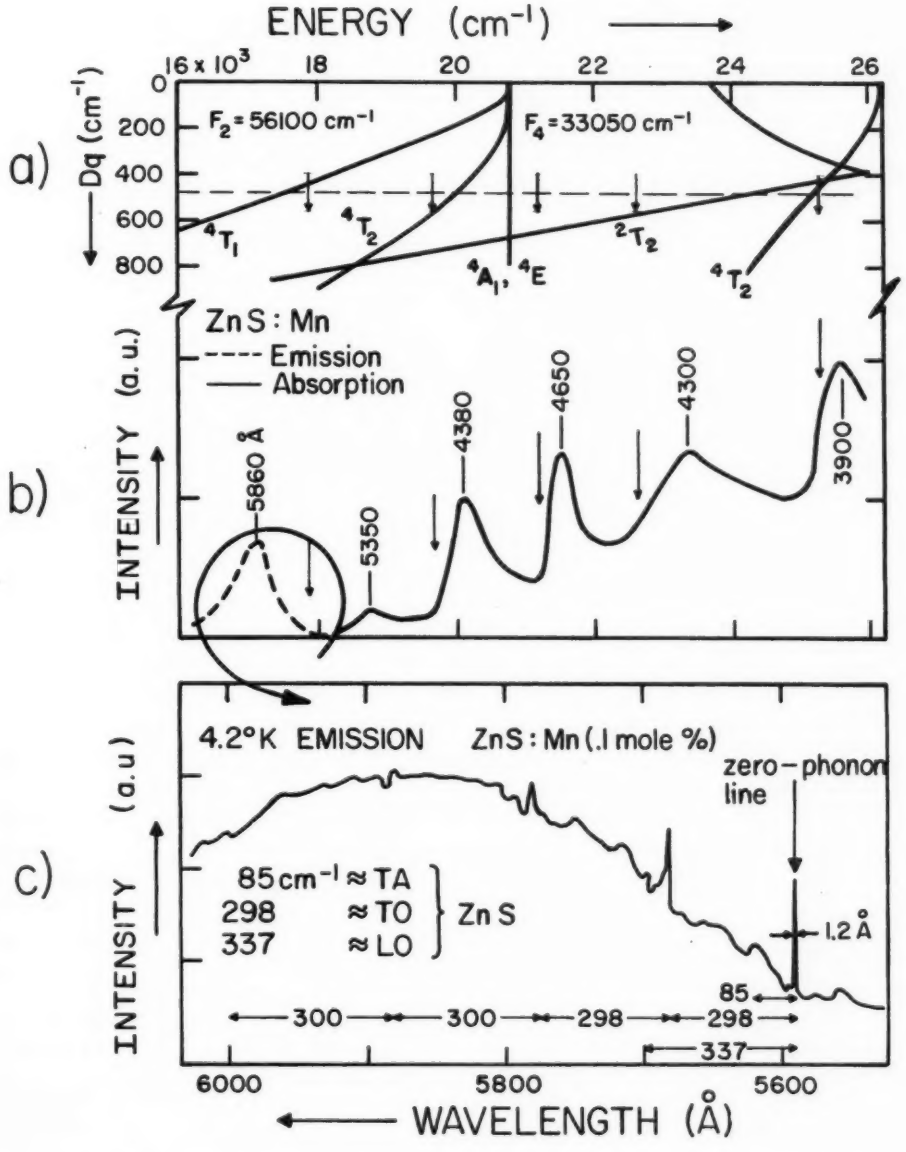
The absorption coefficients of the different bands are relatively small as the parent, free-ion transitions are forbidden and become allowed by perturbations due to one or a combination of the following possible sources: crystalline field, spin-orbit interaction, exchange coupling of Mn^{2+} pairs or phonon coupling. It remained a question as to which of these mechanisms plays the dominant role.

The experiments recently performed at ARL showed that all absorption and emission bands of Mn-activated ZnS (and some similar crystals) at $4.2^{o}K$ consist of a large number of subbands or lines as long as one uses a sufficiently low Mn concentration. Most of these lines we identify in terms of phonon emission coupled to a parent, electronic transition.

The ZnS single crystals used were either of predominantly hexagonal or nearly perfect cubic structure, with various Mn concentrations between 0.07 and 1.0 mole %. The lines showed up consistently in all crystals, and a systematic difference between samples of hexagonal and cubic structure was observable.

The densitometer trace of the luminescence band, e.g., (fig. c), shows structure at the high-energy side of the maximum, which becomes less distinct toward the peak of the emission band. Similarly, in absorption, a line structure is observed. The structure appears at the low-energy side of the absorption-band maxima. In the absorption band of lowest energy, the structure appears as a mirror image of that in the emission band with the "mirror plane" at about 5584 Å. The sequence of line separations actually is similar in the next higher absorption bands. The recurrent line separations of 80-90, 298-302 and 333-347 cm^{-1} were identified to be the energies of the TA, TO

*A detailed report on this subject has been submitted to the Physical Review for publication.



The theoretical energy differences between the various excited states and the ground state of the Mn^{++} impurity ion in a ZnS host lattice are shown in a) as a function of the crystal-field splitting parameter Dq, which measures the strength of the crystalline electric field. The observed optical and emission spectrum of ZnS:Mn is shown in b). The energy differences in a), measured in atomic-energy units (cm^{-1}), correspond to wavelength scale (Å) of b) in that an electronic transition to the ground state from any point of a) would give rise to light of a wave length found immediately below the point in b). The detailed emission band is shown in c). Phonon structure and the zero-phonon line become evident.

The position of the zero-phonon line of each band is indicated by arrows in b) and a). The values of the three zero-phonon lines of lowest energy were used to determine the "best" values of Dq, F_2 and F_4 in a). The "best" Dq = 480 cm^{-1} is indicated by the dashed line in a). The positions of the two zero-phonon lines not used for the calculation can be seen to be in fair agreement with the calculation, and thus serve as an independent check on the assignments of the energy levels.

and LO (transverse acoustic, transverse optical, and longitudinal optical) phonon modes of the ZnS host lattice.

In summary, the most important conclusions to be drawn from our observations are:

1) The usually observed width of absorption or emission bands of ZnS-type crystals containing Mn^{2+} is primarily due to phonon coupling to the electronic transitions.

2) Three of the phonon frequencies observed to couple were identified as the frequencies of TA, TO and LO modes of the ZnS lattice.

3) The knowledge of the exact values of the zero-phonon transitions made possible better crystal-field calculations (which hitherto used the values of the broad-band maxima instead of the zero-phonon lines at the onset of each band). An analysis carried out by Dr. Robert Euwema in this Laboratory shows the crystalline field of ZnS to be $Dq = 480\ cm^{-1}$.

Finally, it should be pointed out that the experiments have added a new example to the few known cases in which zero-phonon lines and phonon-assisted bands are simultaneously observable. A number of interesting studies may follow, since actually this case forms the optical analog of the Mossbauer effect (3). Coefficients describing the coupling to different modes might be determined. The fact may be exploited that there are differences between the phonon frequencies observed by us and some values reported for lattice phonons, and that there are also differences of the order of a few wave numbers between corresponding phonon energies in different bands. The explanation might be sought in the local perturbation of the lattice by the Mn impurity. Also, different excited states of the Mn^{2+} may form different perturbation centers in the host lattice. ★

(1) Kroeger, F. A., Physica Haag, 6, 764, 1939.

(2) Sugano, Y. and J. Tanabe, Phys. Soc. Japan, 9, 753 and 766, 1954. reviewed: D.C. McClure, Solid State Physics, Vol. 9, 1959.

(3) Fitchen, D.B., et al, Phys. Rev. Letters, 11, 275, 1963, and references given therein.

ionospheric ducting confirmed in satellite experiment

SPACE PHYSICS LABORATORY, AFCRL

In a satellite experiment conceived and performed by AFCRL, it has been demonstrated that a radio signal from a satellite can be trapped between two layers of the ionosphere and channeled at least halfway around the world. The AFCRL experiment, known as ORBIS (Orbiting Radio Beacon Ionospheric Satellite), was carried aboard an Air Force satellite launched in November. The satellite beacon operated at 10 Mcps.

The ionospheric ducting phenomenon has been postulated for a number of years, but could not be fully explored before the ORBIS experiment. By ionospheric trapping, radio waves may be transmitted completely around the world. When they emerge from the duct, they can be detected at ground stations. In a cooperative effort, AFCRL arranged for ground monitoring stations to be operated by government and university scientists in nearly 20 nations. The stations are spread throughout both hemispheres.

Very-early results show that ducting has been observed in at least three instances. Two of these are of special interest. A signal from the satellite transmitted over the Indian Ocean was received at the AFCRL Hamilton, Mass. site. At a site in Calcutta, the 10-Mcps satellite signal was recorded over a period of 40 minutes.

The experiment was suggested by Dr. Jules Aarons of AFCRL. John Mullen is project scientist. ★

TO OUR READERS

CORRECTION

In the January 1965 issue, we announced that Dr. Hans J. P. *von Ohain and* Major Melvin R. Keller *of* ARL *had won the first-place award, and* Dr. Harry A. Lipsitt *of* ARL *the third-place award at the* 1964 11*th Annual Air Force Science and Engineering Symposium at* Brooks AFB, Texas. *This was in error. These awards were for the special* OAR *command competition only which preceded the symposium. Final awards to* OAR *scientists at the* 11*th* S&E *Symposium were as follows: First place:* Dr. Harry A. Lipsitt, ARL; *Second place:* Mr. Richard S. Allens, Dr. Jules Aarons *and* Mr. Herbert E. Whitney *of* AFCRL.

In addition, the first Patricia Kayes Glass Award was presented to Dr. Nannielou H. Dieter *of* AFCRL.

The editor sincerely regrets any confusion that may have resulted from a misinterpretation of information previously made available.

OAR (RRYC)
BLDG T-D
WASH, D. C. 20333
UNITED STATES AIR FORCE
OFFICIAL BUSINESS

POSTAGE AND FEES PAID
DEPARTMENT OF THE AIR FORCE

USAFA(DFSLB)
USAF Academy, Colo. 80840
REV 02/05

"RESEARCH - The Key to Aerospace Superiority"